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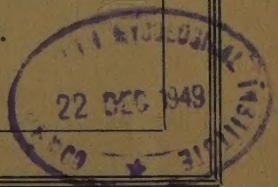

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THE NEW ZEALAND

Journal of Science and Technology

VOLUME 30, No. 2, 1948

(AGRICULTURAL RESEARCH SECTION)

CONTENTS

	PAGE
Preliminary Aerial Distribution Trials with Superphosphate and Seed Mixtures. *D. A. Campbell*	65
Review: The Use and Misuse of Shrubs and Trees as Fodder. *Imperial Agricultural Bureau*	77
An Inherited Straw Weakness in Wheat. *S. W. Boyce*	78
Note on the Estimation of Bacterial Populations. *P. B. Hutchinson*	81
Light-Leaf-Spot of Brassicas. *H. C. Smith*	83
Sulphur Dioxide and Storage Life of Dehydrated Apples. *J. L. Mangan*	88
Tests with D.D.T. and Gammexane on the Larvae of a Dermestid Beetle (*Attagenus Sp.*), a Pest in Some New Zealand Woollen Mills. *R. A. Harrison*	100
Copper Deficiency of Onions Grown on Peat. I. Preliminary Report. *A. F. R. Adams*	105
Spectrophotometric Determination of Cobalt in Pastures and Animal Tissues. *K. J. McNaught*	109
Soil Disinfection: VII. Comparative Value of Formaldehyde and of Paraformaldehyde in Control of Verticillium-Wilt. *H. Jacks*	115
Soil Disinfection: VIII. Chemical Control of Verticillium-Wilt of Tomatoes. *H. Jacks*	118
Soil Disinfection: IX. Control of Eelworm in Outdoor Soil. *H. Jacks*	123
Review: Biological Standardization of the Vitamins. *K. H. Coward*	127

NOTICES

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THE NEW ZEALAND

JOURNAL OF SCIENCE

AND

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Editor: D. Cairns, M.Sc. (Assistant Editor: M. O'Connor, M.Sc.) Department of Scientific and Industrial Research, Wellington

VOL. 30, SEC. A AUGUST, 1948 NUMBER 2

PRELIMINARY AERIAL DISTRIBUTION TRIALS WITH SUPERPHOSPHATE AND SEED MIXTURES

By D. A. CAMPBELL, Soil Conservation and Rivers Control Council, Public Works Department, Wellington

(*Received for publication, 15th December, 1948*)

INTRODUCTION

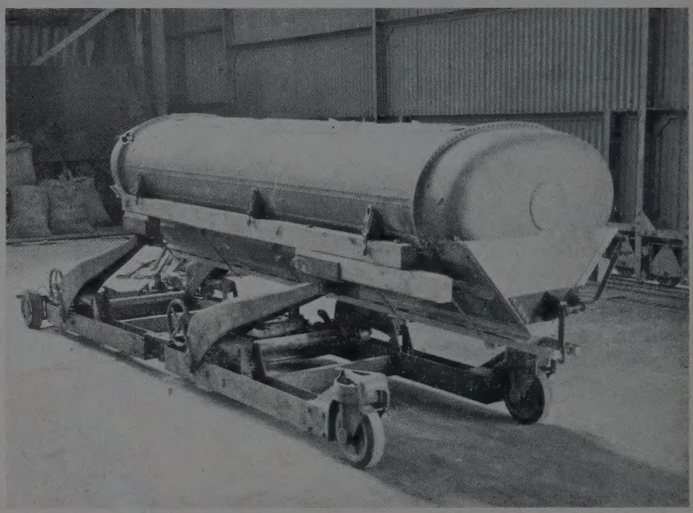
THE problems of combating depletion of pastures and controlling soil erosion and excessive run-off on sown and native hill country grasslands are becoming increasingly acute owing to the cost and scarcity of labour and lack of access. The most immediate conservation problem is improvement of the sward and the most effective large scale remedies are topdressing to improve fertility and seed sowing to provide responsive clovers and grasses. The possibility of using aircraft for these purposes consequently merits full investigation. To be effective the measures of sowing are necessarily coupled with prudent grazing, pest and fire control; trials were therefore made where the latter safeguards were assured. The preliminary aerial-fertilizer trials were confined to typical North Island hill country pastures and the seeding trials were carried out on typical depleted South Island high country native pastures.

HISTORY

The possibility of applying fertilizers and seed from aeroplanes led the writer to investigate and formulate proposals which were adopted by the Soil Conservation and Rivers Control Council in 1947. These proposals were further considered at the Council's request by an expert Interdepartmental Committee consisting of the Departments of Works, Air, Scientific and Industrial Research, Agriculture and the Soil Conservation Council. This committee advised that the seed sowing trials be done by Aerodromes Services, Ministry of Works, and the fertilizer trials by the Royal New Zealand Air Force.

FERTILIZER TRIALS

From the beginning it was recognized that the object of these trials was to provide information on the mechanics of distribution, the design and type of aircraft most suitable, and the practicability of the project. Early consideration was given to using concentrated phosphate, but as this was expensive and difficult to procure, it was decided to use



(*R.N.Z.A.F. Photo.*)

FIG. 1.—Fertilizer Hopper adapted from a Reserve Petrol Tank.

FIG. 2.—Fertilizer Distributor fitted to Avenger Aircraft.

commercial super for the preliminary trials. In the event of the trials being successful concentration of phosphate could then be investigated along with other problems that arose.

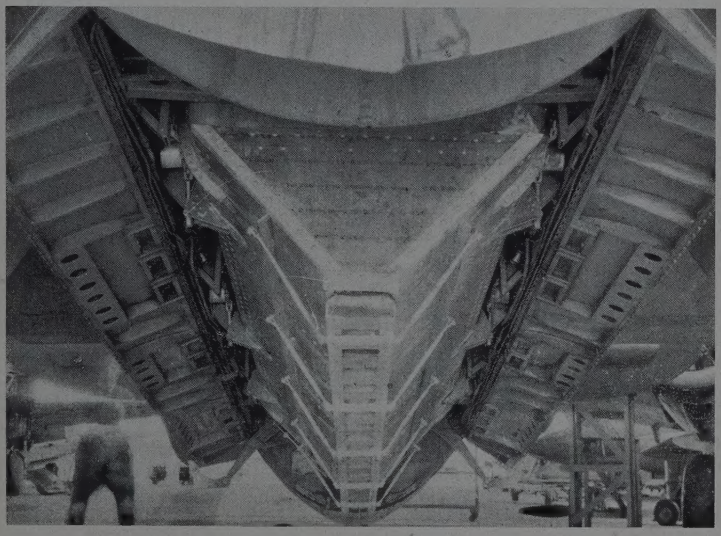
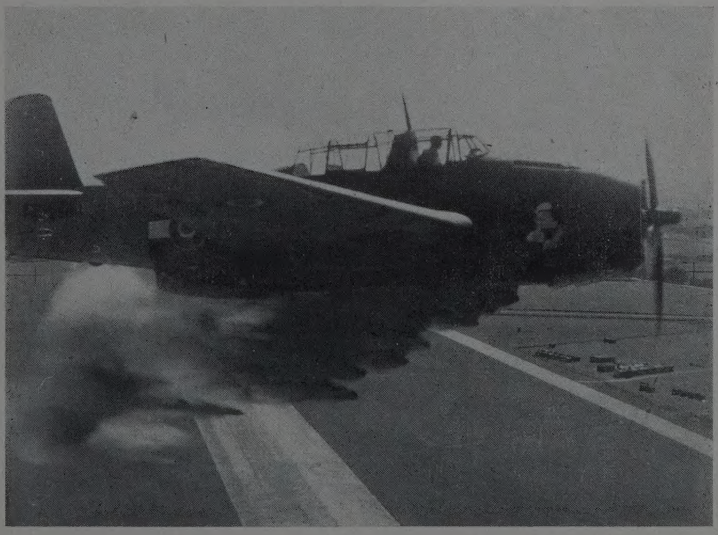


FIG. 3.—Close Up view of Fertilizer Hopper. (*R.N.Z.A.F. Photo.*)



(*R.N.Z.A.F. Photo.*)

FIG. 4.—Hillside Superphosphate being released from an Avenger Aircraft.

The Air Force undertook the preparation of an aircraft for these trials. As ground freight costs were lower than air freight, a large machine designed to carry big loads for long distances was not so desirable for preliminary trials as one carrying smaller loads and capable of operating from smaller aerodromes from which it would virtually lift and distribute the load rather than transport it. As costs of adapting a large aircraft, and investigations into overcoming the dust problem were scarcely warranted in the initial trials, the most suitable machine carrying a relatively small external load was sought ; the most suitable available being an Avenger Torpedo Bomber capable of carrying a 2-ton load. To this machine the Air Force attached a fertilizer hopper (a reserve petrol tank) (Figs. 1, 2 and 3) in the bomb-bay and fitted it with distribution slots and controls designed to discharge at the rate of 2-cwt. per acre a load of one ton of " hill-side " superphosphate, a special granular form of material in which the granules pass a $\frac{3}{8}$ in. mesh but are retained on a $\frac{1}{4}$ in. mesh. With the machine travelling at 125 miles per hour the load had to be dispatched in 37.5 sec.

Calibration Trials with Aeroplane

These trials were carried out at Ohakea by flying across the concrete runways at varying heights with two types of superphosphate—normal commercial and " hillside " superphosphate.

In the first trial carried out in a light wind the cloud of dust from the normal super drifted off the areodrome, and only a small proportion of heavier granules settled on the trial area. Further trials were carried out with " hillside " super, both across wind, into the wind, and with the wind, at elevations of 70 ft., 100 ft., 200 ft., 400 ft. and 600 ft., at a speed of 125 mph. (Fig. 4).

The swathe of " super " pellets was reminiscent of hail both during their fall and on the runway. The width of the swathe varied directly with the height of the aircraft, from 12 yd. width at 70 ft. to approximately 180 yd. at 600 ft. As was expected, cross winds carried the super very appreciably leewards. At 400 ft. elevation a very light breeze deflected the falling super by half the width of the runway (40 yd.).

During the trials sampling boxes similar to those to be used in the later trials at Raglan were difficult to locate so as to completely sample the swathe of super to be dropped in any one run.

However, the most effective sampling was done by sweeping up the super from the 10 sq. yd. hexagons of concrete with which the runway is paved. It was thus possible to measure accurately the transverse and longitudinal distribution of the fertilizer.

The following weights from alternate hexagons along the centre of the line of flight provided a check on the continuity of flow :—

From 400 ft. flying height : 2.45, 2.49, 2.60, 2.57, 2.16, 2.55, 2.37, and 2.36 cwt. per acre.

From 600 ft. flying height : 2.35, 2.12, 2.13, 1.83, 1.90, 1.70 cwt. per acre.

The transverse distribution was carefully checked at 17 ft. 4 in. intervals across the line of flight and recorded as follows :

From 400 ft. flying height : average of pairs of samples. .01, .16, .47, 1.04, 1.78, 2.58, 2.54, 1.82, 1.25, .65, .31, .02 cwt. per acre.

From 600 ft. flying height : .03, .07, .10, .17, .28, .39, .61, 1.08, 1.43, 1.83, 2.13, 1.38, .73, .51, .42, .25, .14, .08, .06, .01 cwt. per acre. (Fig. 5).

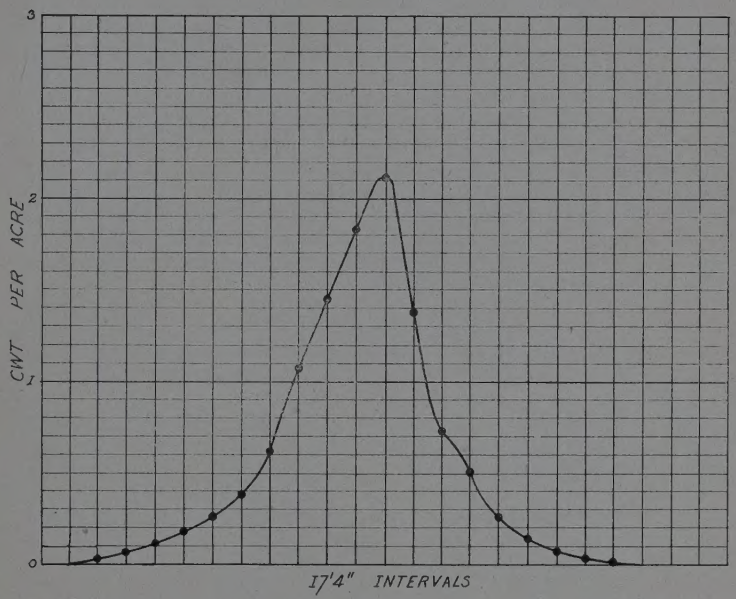


FIG. 5—Distribution of "Hillside" Superphosphate from 600 ft. flying height.

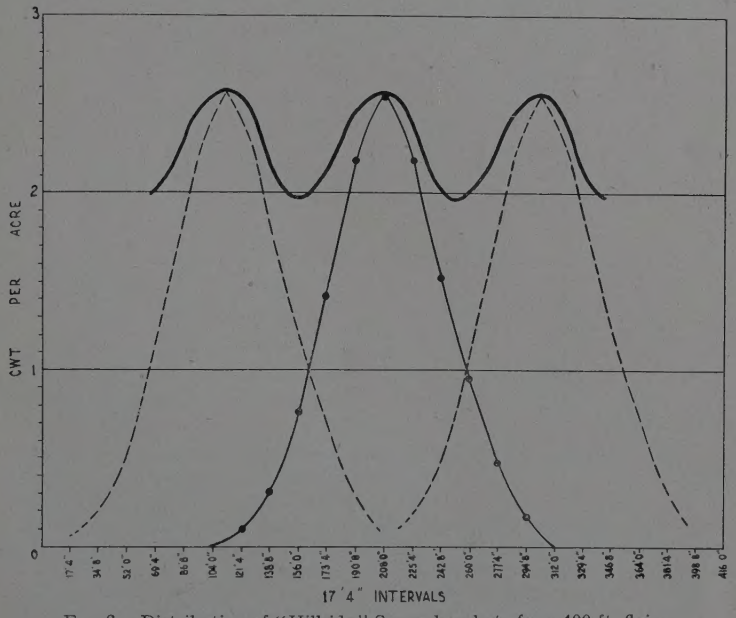


FIG. 6.—Distribution of "Hillside" Superphosphate from 400 ft. flying height, and Effective Distribution in parallel flights 90 ft. apart.

From a graph of these distributions it was calculated that at 400 ft. elevation a spread of 2 cwt. per acre and over was obtained over a swathe of 50 ft., and that by making successive runs at 90 ft. intervals, a top-dressing of from a minimum of 2 cwt. per acre to a maximum at the centre of each flight of 2.5 cwt. per acre could be obtained, providing that the wind did not vary. (Fig. 6). Errors caused by variable winds, had, however, to be accepted in practice on hill country.

In the practical trial, which followed, the required 2-cwt. per acre distribution was closely approximated over a width of 50 ft. at 400 ft. elevation, a suitable flying height for hill country. From a study of the graph it was determined that the aircraft would be required to fly parallel courses 90 ft. apart to ensure that the minimum dressing of 2-cwt. per acre was applied on the periphery with a maximum of $2\frac{1}{2}$ cwt. per acre in the centre of the strip.

The most remarkable outcome of the trials was the distribution effect of the slipstream on the falling particles. This, superimposed on the normal dispersive eddies created by the falling particles, gave unexpectedly effective and wide distribution of the granulated "hillside" superphosphate.

The preliminary trials proved that a sufficiently satisfactory ground distribution of granulated "hillside" super was possible from a fertilizer distributor fitted to an Avenger aircraft flying at a height and speed suitable for hill country. Rapidly changing strength and direction of wind would cause vagaries in the distribution of fertilizer to be overcome only by choosing suitable weather for field scale trials. The expeditious loading and delivery of the fertilizer coupled with the satisfactory spread warranted further trial on a field scale in order that costs and practicability could be further investigated.

TABLE I. SIEVE ANALYSES—BULK SAMPLES

Superphosphate used in Ohakea trials, 21.9.48

Sieve Number.	Sieve Hole Size. (in.)	Percentage of Fertilizer Retained on Each Sieve.	
		Hillside Super.	Commercial Super.
4	0.197	88.9	0.0
10	0.0787	7.5	0.0
20	0.0331	0.7	12.6
40	0.0165	0.6	47.5
60	0.0098	0.3	16.0
80	0.0070	0.2	8.5
100	0.0059	0.4	4.25
100	0.0059	0.9	10.3

Raglan Field Trials

Typical hill country with poor access and sloping steeply from 600 ft. to 200 ft. elevation was chosen on the late J. B. Vowles' property at Te Mata, south of Raglan. On this farm a moderately good mixed pasture of ryegrass, cocksfoot, dogstail, danthonia, white clover and subterranean clover had been established during the previous 25 years on hitherto heavy mixed podocarp forest land.

The Air Force photographically surveyed the location and prepared a flying plan and organized 3-way radio communication between ground,

air and base staff. Smoke indicators were lit and moved over appropriate distances prior to each flight.

The Avenger aeroplane operated from Rukuhia Aerodrome some 20 miles distant, and after an establishing run was made, came in over the ridge and descended parallel to the slope of the trial area.

Officers of the Soil Fertility Research Station, Department of Agriculture, who undertook to measure the ground distribution and collate the information on the subsequent response to "super", placed boxes padded with scoured and weighed wool at intervals over the 27 acre trial area. During the operation the ground distribution was directly checked after each run by collecting and counting the granules that fell on a unit square yard, and the information was communicated to the Control Officer.

From the flying point of view the trial was very satisfactory, but unfortunately the superphosphate did not flow freely owing to the high proportion of fine material in the sample. This was apparent in the field, as the first "hail" of pellets which hit the ground in approximately 12 sec. was followed some seconds later by much finer particles and finally dust. However, for the third and final trip the more granular sacks of "super" were chosen and the load dispatched in runs over the target area as originally planned.

The Department of Agriculture reported that :—

1. the wool-padded boxes placed on a series of parallel lines along the proposed lines of flight trapped the falling fertilizer at the average rate of 13.5 g. per sq. yd. or 144 lb. per acre ;
2. from the square yard wire frames used additionally in transverse sampling of the entire area an average of 6.7 g. per sq. yd. or 72 lb. per acre for 49 samplings was obtained.

   Allowing for a 50 per cent. recovery by this method owing to the fine material present, these sample weights compare favourably with the box samplings.
3. the total of $2\frac{1}{3}$ tons dropped on the target area of 27 acres indicated an average distribution of $1\frac{2}{3}$ cwt. per acre.
4. an analysis of a composite sample of the super from 32 sacks was as follows :—

TABLE II. ANALYSIS OF HILLSIDE SUPERPHOSPHATE USED IN RAGLAN TRIALS

			Retained on	$\frac{1}{4}$	in. sieve	25.1	per cent.
Passed	$\frac{1}{4}$	in. and	,, ,,	$\frac{1}{9}$	,, ,,	8.9	,, ,,
,,	$\frac{1}{9}$	,, ,,	,, ,,	$\frac{1}{16}$	,, ,,	5.7	,, ,,
,,	$\frac{1}{16}$	,, ,,	,, ,,	$\frac{1}{25}$	,, ,,	7.8	,, ,,
			Passed	$\frac{1}{25}$	,, ,,	52.5	,, ,,

(Only 25 per cent. of this sample was retained on the $\frac{1}{4}$ in. sieve)

The ground measurements made, correlated well with the total weight dropped when allowance was made for the unexpectedly large proportion of fine material in the sample, some of which probably drifted with the wind off the area.

In view of the fact that by double screening the manufacturers can assure supply of a satisfactory uniform sample of "hillside super" in future, the field trial must be regarded as being highly satisfactory in proving the practicability of aerial topdressing of average New Zealand hill country.

AEROPLANE DISTRIBUTION OF SEED MIXTURES

Further investigation of seed sowing from the air was necessary to determine the practicability of the operation in view of the widespread need to promote soil conservation by introducing legumes onto North Island hill country pastures and grasses and legumes onto South Island high country native pastures. In the past surface sowing trials have proved to be effective overseas (1) (2) and in New Zealand in assisting the recuperation of this country notably at Molesworth, Mt. Pisa and on "The Bluff's" Run.

From earlier experience in the sowing of lupin seed on sand dunes and the application of cobalt and copper sulphate on trace-element deficient areas, A. M. Prichard, pilot to Aerodrome Services, Ministry of Works, designed and fitted a suitable hopper in a Whitney Straight light aeroplane capable of carrying 400 lb. of seed.

A venturi was arranged to effect a forced dispersion of the seed as it flowed from the hopper by gravity, and the controls were designed to regulate the rate of flow according to speed and height of the aircraft and provide a constant 10 lb. per acre distribution of the mixture sown.

Calibration and Distribution Trials

These were carried out at Rongotai Aerodrome using a mixture of grasses and clovers suitable for high country containing clovers (white, red and subterranean), grasses (cocksfoot and brown top) and yarrow.

In the first trial, flying at an altitude of 100 ft. into a 17 miles per hour wind at a speed of 100 miles per hour, the brown top and yarrow components of the mixture drifted down wind by more than 300 yd. and could not be recorded .

Counts were made of all seeds falling in alternate square yards across the line of flight and recorded.

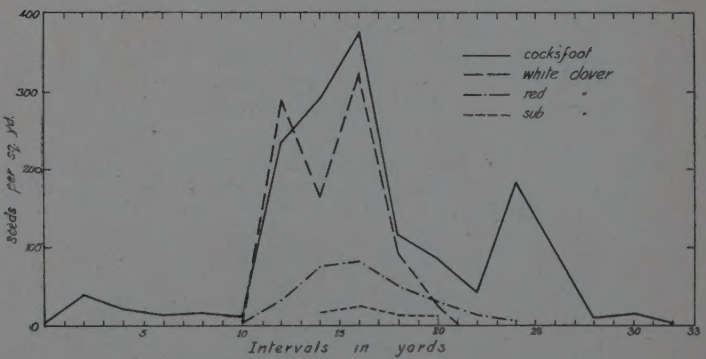


FIG. 7.—Distribution of Seeds released from a plane flying at 100 ft. height into 17 miles per hour wind.

Two trials were subsequently made under calm weather conditions, at 200 ft. and 400 ft. flying height with the composite mixture of grass and clover used in the first trial in order to determine the pattern of distribution under ideal conditions. Counts of seeds were made directly

on the Tarmac using a unit square yard in the first trial, and in the second the seed falling was collected on sheets of cloth 20 sq. ft. in area placed at 5 ft. centers across the line of flight.

The ground distribution of the different types of seeds dropped in the three trials are indicated in the following table and in the accompanying graphs (Figs. 7-9).

TABLE III. GROUND DISTRIBUTION OF SEEDS DROPPED FROM AIRCRAFT AT HEIGHTS OF 100 FT., 200 FT. AND 400 FT.

Seed.	Rate per Acre. (lb.)	No. of seeds required per sq. yd. at rate intended.	Width of Distribution. (yd.)	Average No. of seeds per sq. yd.	Average No. of seeds per sq. yd.
Flying height 100 ft.					*over 10 yd. swathe.*
Cocksfoot	5	500	40	80	221
Red Clover	2	88	20	30	55
White Clover	1	100	14	132	184
Subterranean Clover	1	20	8	18	17
Flying height 200 ft.					*over 17 yd. swathe.*
Cocksfoot	5	500	48	306	540
Brown Top	½	1550	20	81	84
Yarrow	½	360	22	99	108
Red Clover	2	88	30	41	72
White Clover	1	100	18	50	156
Subterranean Clover	1	15	28	18	18
Flying height 400 ft.					*over 39 yd. swathe.*
Cocksfoot	5	500	76	204	415
Brown Top	½	1550	63	402	788
Yarrow	½	360	60	37	85
Red Clover	2	88	50	88	160
White Clover	1	100	42	171	246
Subterranean Clover	1	15	50	15	26

From the graphs of distribution of individual components of the mixture a compromise was made between effective ground distribution and suitable flying height to determine the distance between the parallel flights.

On the Soil Conservation Reserve, Omarama, 100 acres of severely depleted and eroded North Western slopes of Omarama soil type were seeded at approximately 10 lb. per acre with a mixture of cocksfoot 6 lb., brown top ½ lb., white clover 1 lb., subterranean clover 2 lb., and yarrow ½ lb. per acre.

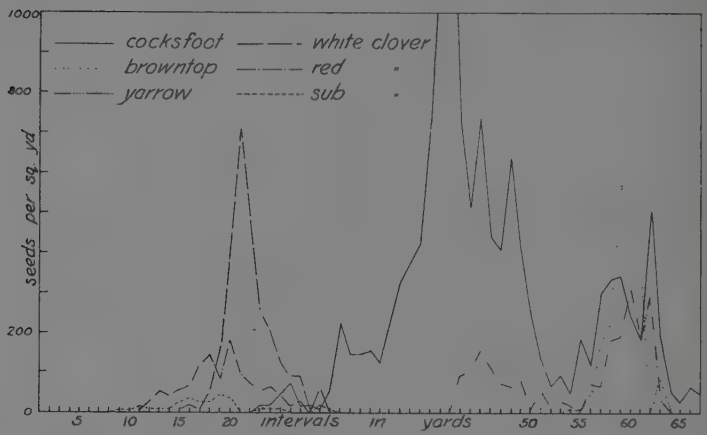


FIG. 8.—Distribution of seeds released from a plane flying at 200 ft. height on a calm day.

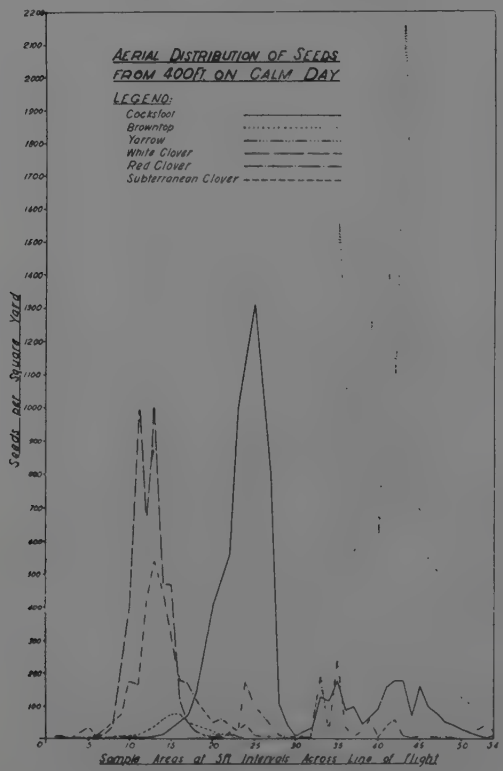


FIG. 9.—Distribution fro m 400 ft. on a calm day.

A temporary landing strip from which the machine operated was made on the adjacent flats by filling in some rabbit warrens, and the Army provided walkie-talkie equipment to provide communication between the observer on the hillside and the pilot when he landed to re-load.

Despite a wind of 20-25 miles per hour velocity the trial was carried out and a satisfactory ground distribution was obtained by flying on approximate contours working in parallel strips 2 chains apart from the base towards the top of the slope. The fact that the whole operation was carried out in approximately 1 hour indicates the possibilities of cheaply sowing very large areas.

"Campden" Awatere Valley

Arrangements were made to sow a 50 acre trial block on the property of Mr. I. Cameron who had successfully surface sown depleted pastures in the past. Ideal ground conditions were obtained at the close of the frost season (September 30th) when the loose cracked soil was still moist.

However, on this typical high country (3,000 ft.) with its steep slopes and deep valleys, upper wind conditions were found to be dangerous for flying, although the ground weather conditions were ideal. In the runs made it was possible to lap the seed sown on each run but the winnowing effect of the clovers from the grasses in falling resulted in separate strips of these being sown on the ground. This would, however, be of little practical consequence if a large area was sown in a steady wind. Reports from ground observers confirmed the satisfactory spread of the seed on the ground.

Gisborne Hill Country

An early trial was made with sowing one pound per acre each of white clover and lotus major on this well grassed but clover-deficient hill country. Mr. Madden, Assistant Director, Grasslands Division, undertook the measuring of distribution.

Plates filled with water were placed 5 paces apart in the valley, on the slope, and along the top of the ridge to measure the distribution. The seed collected in the plates indicated a fairly satisfactory distribution but considerable variation in the numbers of seeds collected in some plates illustrated the effect of wind in modifying the fall of the seeds. However, stock would play a big part in further distributing seeds produced by the established plants.

CONCLUSIONS

The aerial distribution trials have proved that fertilizer can be dropped from aircraft successfully within the desired limits of accuracy, provided the ballistics of the fertilizer are reasonably uniform, and the aeroplane has satisfactory performances under the conditions of terrain involved.

From the preliminary measurements made of the distribution of grass and clover seeds from beneath the fuselage of a single engined plane, the indications are that satisfactory distribution and control of the individual components of the mixture is not obtained owing to the varying ballistics of the seeds. To some extent the problem was solved by sowing across wind in the field trials where a satisfactory distribution

of the larger seeds was reported on the ground. The necessary control of the seed would appear at this stage to involve pelleting or cementing seeds into larger aggregates for aerial distribution.

Investigation Necessary

These trials have brought into sharper focus the need for considerable investigation in four major allied fields if this work is to be developed effectively.

1. Aviation :

Further information is required on the ballistics of falling particles (pellets of fertilizer and seed), the effect of wind, suitable containers and mechanical means of discharge, flying techniques on varying terrain, the effect of meteorological conditions on the periods suitable for flying in various regions, ground and air control of topdressing operations and design of types of aircraft most suitable for seed and fertilizer distribution.

2. Materials :

Investigations are needed to improve the efficiency of materials from the distribution and agricultural aspects. These involve concentration of the fertilizer and improvement of its chemical and physical characteristics to assure lack of corrosion of the container, freedom of flow and control of the material during operations. Variation in chemical content of fertilizers and in mixtures of seeds will probably be required to suit different regions. Further investigations are necessary into the release of seeds from various places on the aircraft and on cementing them into aggregates over which greater control may be obtained. The availability and cost both of fertilizer and seeds are of considerable importance.

3. Transport and Economics :

Thorough investigation is necessary to evaluate the costs of aerial and normal topdressing in order to define the areas best serviced by each technique. Availability of and supply of fertilizer to aerodromes is basic to costing which may best be done on a self-contained commercial basis when suitable equipment and methods have been evolved. When these questions have been determined the most suitable method of allocating the cost among those receiving benefit—the landowner, the Catchment Board, the Air Force and the State—could be investigated.

4 Agriculture :

Information should be obtained relative to the total areas requiring seeding and topdressing, their location, the type of country and general topography, the proportion of Crown and private property, the most suitable seeding and fertilizing period, the most effective management before and after fertilizing or seeding, and the most critical areas from soil conservation and flood control points of view.

With this information available the Council will be in a strong position to organize a service that will help to achieve its purpose of soil conservation and flood control combined with the maintenance of permanent production from the land.

APPENDIX

Since these trials were commenced farmers have taken an active interest in aerial seed sowing and have contracted with Mr. T. J. Lucas, Managing Director of Southern Scenic Airtrips Ltd. to sow portions of their properties as follows :—

Mr. Scaife, Wanaka—1,500 lb. of seed was sown at the rate of 10 lb. per acre (approx.) at a cost of £10 for the aerial distribution.

Mr. Strain, Lake Hayes—1,800 lb. of seed was sown in 2 hours at the rate of 10 lb. per acre and at a cost of £10 : 10 : 0 for distribution.

Messrs. Saunders and Nelson, Crown Terrace—2,000 lb. of seed was sown in 2 hours at the rate of 10 lb. (approx.) per acre at a cost of £10 for distribution.

Wintersloe Run, Methven, a contract has been undertaken to sow 5,000 acres with a 10 lb. mixture of cocksfoot and white clover at an approximate cost of £166 for distribution.

ACKNOWLEDGMENT

The willing co-operation and enthusiasm of Departmental Offiecrs made these preliminary trials possible, and to the following departments the Soil Conservation and Rivers Control Council is indebted—Royal New Zealand Air Force, Department of Agriculture, Aerodromes Services, Ministry of Works, and Department of Scientific and Industrial Research.

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REVIEW

THE USE AND MISUSE OF SHRUBS AND TREES AS FODDER

IMPERIAL AGRICULTURAL BUREAU JOINT PUBLICATION No. 10 (1947)

pp 231 + XXXV, Price 9/- (sterling).

The importance of this subject, chosen for a joint publication by three of the Imperial Agricultural Bureaux, has been expressed adequately in the opening sentence: " It is a humbling fact for grass pasture experts to realise that probably more animals feed on shrubs and trees, or on associations in which shrubs and trees play an important part, than on true grass or grass-legume pastures, short and tall grass ranges and steppes ". As far as is known it is the first attempt to cover the subject comprehensively. For this reason it is necessarily sketchy but has served to draw attention to the lack of precise knowledge on the subject and to the paucity of investigation and research proceeding over the vast areas concerned. What was originally intended to be a compilation of " uses " has turned out to be equally a compilation of " misuses ", for the grazing of these areas is usually uncontrolled and closely connected with erosion problems and in places with forest management problems.

The main body of the publication consists of a series of contributions by local workers in many countries. Owing to lack of contributors from

Africa (other than the Union), India and Ceylon and the Mediterranean Lands, Near and Middle East these have been written up by R. O. Whyte, the Director of the Bureau of Pastures and Field Crops. Contributions cover Australia and its several states, New Zealand, South Africa, U.S.S.R., United States of America and Canada. An omission would seem to be some of the northern European countries other than Russia. Much stock is for instance depastured in the forest areas of Scandinavia. A section of Latin America has been omitted because the subject has been reviewed in Bulletin 36 of the Imperial Bureau of Pastures and Field Crops, "The Grasslands of Latin America".

A chapter on the chemical composition and digestibility of fodder shrubs is included. This consists of a compiled list giving the results of all analyses made of these plants together with a reference to the original work. The publication is well rounded off with indices of authors and investigations, plant orders, genera and species, a key to common plant names, a geographical index, addresses of contributors and seventy illustrations. Apart from its value to workers interested directly in the subject the publication contains a wealth of information on plant geography of arid areas.

A. L. P.

AN INHERITED STRAW WEAKNESS IN WHEAT

By S. W. BOYCE, Wheat Research Institute, Christchurch, New Zealand*

(*Received for publication, 1st September, 1947*)

Summary

Evidence is given for the presence of a single gene causing pronounced weakness of straw in a *Triticum vulgare* cross.

INTRODUCTION

MECHANICAL breakage of straw in wheat frequently lowers the number of ears harvested and it is generally observed that the loss due to straw break is more serious in some varieties than in others. However, while straw weakness is selected against in economic breeding work, this character has not been studied genetically. The following analysis of an apparent single gene segregation for straw weakness is therefore published, with some reservations as to the reliability of the data which were recorded for a different purpose.

MATERIALS AND METHOD

The inheritance of yield and its components was being studied in a *Triticum vulgare* cross between the lines S 1556(P_1) and S 357(P_2). In recording number of ears per plant (e), the number of mature straws from which the ears had been lost by breakage (e_b) was recorded for each plant, for the purpose of correcting total yields in the final analysis. These breakages may have occurred while the crop was standing in the field, during harvest, or in the final handling of the plants, and no attempt could be made to determine the cause of breakage in any plant. It was

* Now Botany Division, Department of Scientific and Industrial Research, New Zealand.

clear however, that one parent line suffered a much greater amount of damage than the other, the F_1, F_2 and F_3 being intermediate in this respect.

The design of the experiment precludes the possibility of experimental bias ; it was sown in eight beds, each bed being composed of :—

Generation.	Number of Plots.	Number of Plants per Plot.
P_1 and P_2	11	25
F_1	1	25
F_2	1	50
F_3	18	50

Within each bed parent plots, chosen at random, alternated with groups of two hybrid plots, these also being randomized. Plots were harvested in the order in which they were grown, and handled in approximately that order in recording e and e_b.

The assumption of a single gene difference between P_1 and P_2 is tested in two ways : (1) The whole of the data is used as it was recorded, F_3 plot means being used as estimates of F_2 plant means, and compared with theoretical F_2 values based on P_1, P_2 and F_1 plot means. (2) Samples of equal numbers of plants have been drawn at random from each generation, P_1, P_2 and F_1 distributions being used to test expected F_2 and F_3 plantwise distributions.

RESULTS

In Table I the number of broken straws is expressed as the percentage of total ears within each bed, and over all beds.

TABLE I. SUMMARY OF PERCENTAGE STRAW-BREAK PER BED

Generation.	Percentage straw-break per bed.								Per cent. straw-break over all beds.
	1	2	3	4	5	6	7	8	
P_1	14.4	8.6	5.7	27.6	17.4	18.1	22.9	17.2	15.9
P_2	3.7	0.6	2.2	2.9	4.6	3.6	1.9	2.9	2.8
F_1	12.8	3.4	2.2	4.6	9.6	0.6	7.9	14.0	6.8
F_2	4.5	6.6	5.0	5.6	36.2	8.0	2.2	7.1	8.4
F_3	7.7	3.3	2.9	7.8	6.1	5.6	10.1	9.2	6.9

From these figures it is apparent that the F_1, F_2 and F_3 are approximately intermediate in value, but approach P_2 rather than P_1. This may be due to a slight degree of dominance for strong straw, and at the same time, to geometric gene differences. In addition there is a marked correlation between mean and standard deviation of the parents and F_1:—

	P_1	P_2	F_1
Mean	15.9	2.8	6.8
Standard deviation ...	12.2	3.3	5.1

Since there is no genetic variation within parents and F_1, it is apparent that environmental, as well as genetic, variation is geometric. Therefore, geometrically increasing class intervals are used in studying the frequency distributions over all plots. The first class is based on one third of the standard deviation of P_1, including all values from 0-4 per cent., the second class covers from 5-16 per cent. and the third from 17 per cent. upwards. In Table II is shown the actual distribution of percentage breakage per plot, based on this classification.

TABLE II. FREQUENCY DISTRIBUTION OF PERCENTAGE STRAW-BREAK PER PLOT

Generation.	Numbers of plots in groups classified for percentage straw-break.			Total.
	0 - 4 Per cent.	5 - 16 Per cent.	17 Per cent. upwards.	
P_1	30	10	0	40
P_2	5	14	16	35
F_1	3	5	0	8
F_2	1	6	1	8
F_3	56	61	12	129

When dominance is slight, as in this case, the F_3 plot means may be taken as estimates of the genetic values of the F_2 plants which gave rise to them. Using the actual P_1, P_2 and F_1 distributions we can therefore construct theoretical F_2 distributions for comparison with the actual F_3 data. Assuming a single gene difference between P_1 and P_2, the F_2 distribution should be composed of $1P_1 : 2F_1 : 1P_2$. Since the actual F_3 is composed of 129 plots we may take 128 as a close approximation to the actual number; this would give a distribution of $32P_1 : 64F_1 : 32P_2$. Actual P_1, P_2 and F_1 distributions have been transformed into these proportions and summed, giving a theoretical distribution for comparison with the actual (Table III).

TABLE III. THEORETICAL RECONSTRUCTION OF F_3 PLOT MEAN PERCENTAGE e_b FREQUENCY DISTRIBUTION

Generation.	Numbers of plots in groups classified for percentage straw-break.			Total.
	0 - 4 Per cent.	5 - 16 Per cent.	17 Per cent. upwards.	
P_1	24.00	8.00	0.00	32
P_2	4.57	12.80	14.63	32
F_1	24.00	40.00	0.00	64
Theoretical F_3	52.57	60.80	14.63	128
Actual F_3	56.00	61.00	12.00	129
Difference	−3.43	−0.20	+2.63	1
χ^2	0.22	0.00	0.47	0.69
				$P = 0.7$

The χ^2 value (0.69, $P = 0.7$) shows that there is no significant difference between the theoretical and actual distributions. The single gene assumption is therefore not disproved by this analysis.

In order to test the single gene assumption further, a random sample of 150 plants was drawn from each generation, e and e_b being summed for each sample (Table IV).

TABLE IV. DISTRIBUTION OF PLANTS CLASSIFIED ACCORDING TO NUMBER OF BREAKS PER PLANT

Generation.	Number of breaks per plant.					Total e_b	Total e
	0	1	2	3	4 - 8		
Number of plants in each class :— P_1	82	35	20	8	5	125	740
P_2	128	16	2	4	0	32	866
F_1	114	22	9	4	1	60	923
F_2	107	30	7	2	4	69	802
F_3	112	22	7	4	5	70	753

From these data, theoretical F_2 and F_3 plantwise distributions have been constructed, based on the equations $F_2 = 1P_1 + 2F_1 + 1P_2$ and $F_3 = 3P_1 + 2F_1 + 3P_2$. Agreement is again fairly good:—

Class.	0	1	2	3	4-8
F_2 Actual Distribution	107	30	7	2	4
*F_2 Theoretical Distribution	109	24	10	5	2
χ^2	0.04	1.50	0.90	1.80	2.00
Total $\chi^2 = 6.24$, P = .2					

Class.	0	1	2	3	4-8
F_3 Actual Distribution	112	22	7	4	5
*F_3 Theoretical Distribution	107	24	11	6	2
χ^2	0.25	0.17	1.45	0.67	4.50
Total $\chi^2 = 7.02$, P = .15					

* For method of construction of theoretical distributions see Table III.

The above comparison is based on equal numbers of plants. Since the samples did not have equal e values, a final comparison has been made after adjusting all lines to the same e (740) as P_1, using the equations

$F_2 e_b = 1P_1 e_b + 2F_1 e_b + 1P_2 e_b$, and
$F_3 e_b = 3P_1 e_b + 2F_1 e_b + 3P_2 e_b$:

	P_1	P_2	F_1	F_2	F_3
e	740	740	740	740	740
Actual e_b	125	27	42	64	69
Expected e_b	125	27	42	59	68

Agreement is again quite good.

It is therefore concluded that a single gene or closely linked gene complex determines the difference in strength of straw, between S357 and S1556.

NOTE ON THE ESTIMATION OF BACTERIAL POPULATIONS

By P. B. HUTCHINSON, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

IN the course of work involving large numbers of approximate population determinations, a simple meter which uses cultural opacity as a criterion proved invaluable. If approximate estimates are sufficient, determination by relative opacity has several advantages over dilution-plate and microscopic-techniques; time and labour are reduced to a minimum; there is no loss in volume or risk of contamination in repeated estimations of the same culture; both live and dead organisms are included in the estimation.

The apparatus (Fig. 1) consists of a lamp-house which directs light through the sample to be estimated. An adjustable diaphragm is located between the light-source and the sample tube. The tube-holder is slotted and allows a narrow beam of light to pass through the tube to an ordinary photo-electric exposure meter. This gives a direct reading of the light transmitted by the sample.

The culture tubes are previously selected to conform to uniform diameter and wall thicknesses, thus eliminating errors which would arise due to varying optical properties of different-sized tubes. To correct errors due to change in light-intensity a constant voltage source is used. The diaphragm allows standardization of the instrument against check tubes in each experimental series.

The instrument is calibrated empirically against cultures of which populations have been previously determined microscopically. It is thus possible to compute the curve correlating population with relative cultural opacity. Recalibration is advisable for each new batch of medium used; errors arising from varying light-scatter and wave-length are thus minimized.

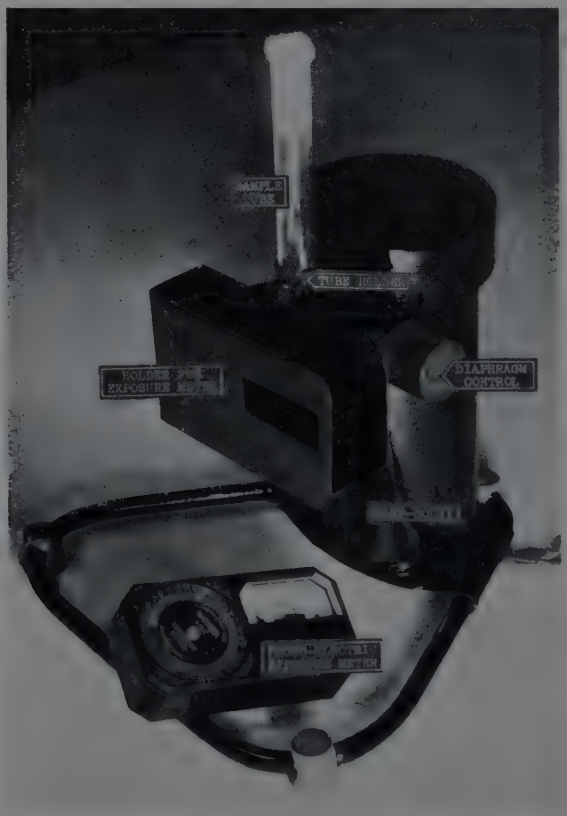

FIG. 1

LIGHT-LEAF-SPOT OF BRASSICAS

By H. C. SMITH, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 1st June, 1948*)

Summary

1. Light-leaf-spot of brassicas caused by *Gloeosporium concentricum* is widely distributed on cauliflowers in market gardening areas near Auckland city.
2. Degree of infection varied from 0 to 100 per cent. in different crops.
3. Characteristic symptoms are leaf distortion and the presence of superficial white spore masses on leaves.
4. The disease is of little economic importance, its effect on yield and quality being slight.
5. There is considerable variation in varietal susceptibility, a number of late maturing cauliflowers and one cabbage variety being immune.
6. The causal fungus grows readily on a variety of media but growth is slow.
7. Infection was secured in both field and cold frame by artificial inoculation of plants, symptoms appearing after 20 days.

INTRODUCTION

LIGHT-LEAF-SPOT of brassicas is widespread in England where it has been recorded on broccoli*, cauliflowers and spring cabbage (Moore, 1943). The fungus causing this disease was recorded in New Zealand by Cunningham (1944) under the original name *Cylindrosporium concentricum* Grev. ex Fr. Use of the combination *Gloeosporium concentricum* (Grev.) Berk. and Br. has been recommended by the British Mycological Society (Moore, 1939), since retention of the species under *Cylindrosporium* would so alter the concept of this genus that changes in 155 specific names would become necessary.

INCIDENCE

Light leaf-spot is widely distributed on cauliflowers in all market gardening districts in the vicinity of Auckland. Occasionally cabbage plants also are attacked, but in three cabbage crops at Pukekohe no infected plants were seen.

On cauliflowers incidence of light leaf-spot varied from nil to 100 per cent. In most crops where the disease was present every plant was infected but there were wide differences in the amount of leaf area affected. To secure information concerning severity of attack the approximate percentage of leaf area diseased was used in assessing degree of infection. For the purpose of comparison three grades were used: (a) Nil—no infection, (b) moderate—0-50 per cent. leaf area diseased, (c) severe—50-100 per cent. leaf area diseased. Degrees of infection in the crops inspected are shown in Table I.

* In this paper broccoli varieties are included as late maturing cauliflowers.

TABLE I. DEGREE OF LIGHT-LEAF-SPOT INFECTION ON CAULIFLOWERS IN THE AUCKLAND AREA

District.	Season.	Number of Crops infected. (percentage leaf area infected)			
		No Infection.	0-50 per cent.	50-100 per cent.	Total No. Crops.
Mangere	June-July	9	4	1	14
Pukekohe	June-July	3	2	0	5
Avondale	July-August	0	1	0	1
					20

In no case did the disease appear to be of economic importance. The single instance of severe infection was a poorly grown crop of an early maturing variety grown out of season. The crop at Avondale showing 50 per cent. infection was again recorded after marketable cauliflowers had been cut, to measure the losses caused by this disease. One tenth of the cauliflowers had been rejected for various reasons, e.g. small size, and open curd, but only 20 per cent. of these showed severe infection with light leaf-spot. Thus the number rejected because of this disease could not have amounted to more than 2 per cent. of the total crop.

SYMPTOMS

The disease may be found at any time of the year, but appears to develop most readily under cool rainy conditions and on slow growing plants. The main symptoms in the field are distortion of leaves, and a white film of spores. Lesions occur independently on both leaf surfaces and on stems as circular or irregular light coloured patches surrounded by concentric circles of small white spore masses (Fig. 1). The most characteristic symptom of severe infection is malformation of leaves (Fig. 2). Size of lesions varies from about half an inch to three inches or more in diameter. Infection of the whole leaf surface has been obtained by artificial inoculation, but is rare in the field. Spores are pushed out in minute white tendrils on to the leaf surface. These tendrils are flattened by dew or rain to form a white film resembling spray residue. Heavy rain however, quickly washes away the spores. Irregularly shaped black spots may appear in the positions previously occupied by spore tendrils, but these are superficial only. A later symptom of severe infection is a silvering of the leaf surface, caused by lifting of the cuticle.

GROWTH IN CULTURE

The fungus was isolated by transferring spores from a diseased cauliflower leaf to cabbage leaf extract agar (200 g. cabbage leaves, plus 200 ml. water, plus 8 g. agar agar). Subsequently the fungus was transferred to potato dextrose agar, prune agar, malt agar, and Czapek's synthetic media. It spored freely except on Czapek's media, on which it remained sterile. Growth was slow on all media. Optimum temperature for growth in culture was found to be 20°c.

MORPHOLOGY

Development of the fungus in the leaf is superficial, as hyphae are found only within the cuticle. Spores are budded off from thickened

hyphae which form an acervulus also in the cuticle (Figs. 3 and 4). As spores increase in number pressure ruptures the cuticle and they are forced through the opening forming a tendril. Spores from cauliflower leaves have an average size of $10.0\mu \times 2.4\mu$ and a range of 6.5 to $14\mu \times 2$ to 3μ. These dimensions are in agreement with measurements recorded by Thomson (1935). Spores are allantoid, often slightly curved, single celled (or occasionally one-septate) and have rounded ends. They germinate with a single polar germ tube, usually forming a septum across the spore somewhere between the centre and the germ tube end.

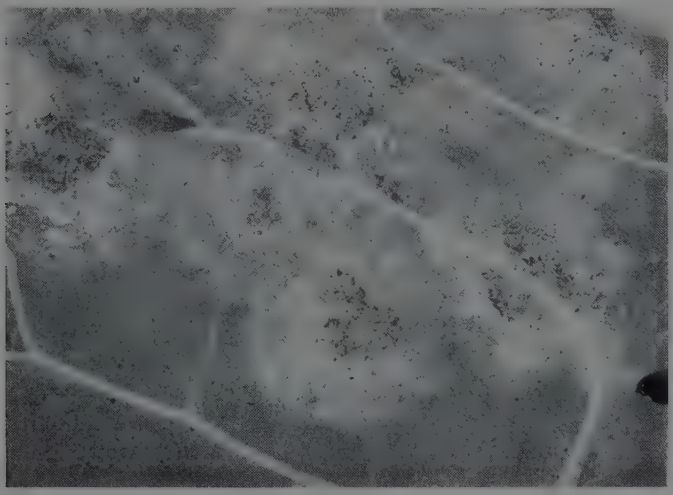

FIG. 1—Typical lesion on cauliflower leaf showing concentric spore masses and white film of spores. X2.

FIG. 2.—Left: healthy cauliflower. Right: severely infected cauliflower with distorted leaves.

INOCULATIONS

Cauliflower seedlings of Phenomenal Early variety were grown in April and planted both in the field and in the cold frame. They were inoculated at fortnightly intervals with spores firstly from diseased leaves and later from culture. All plants became infected 20 days after inoculation both in the field and in the cold frame.

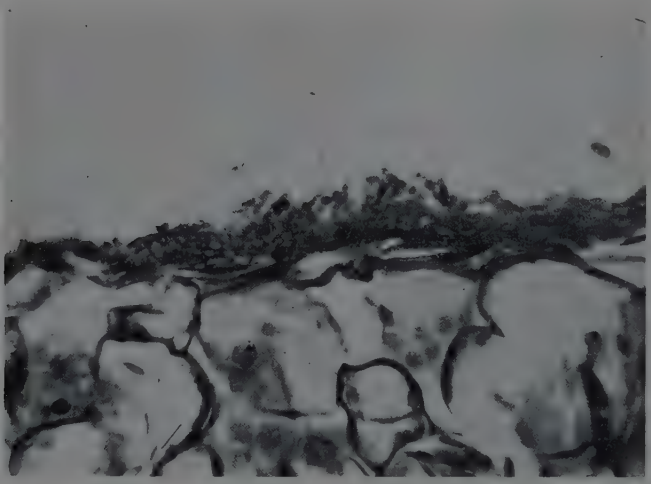

FIG. 3.—Transverse section of an acervulus on a cauliflower leaf, showing hyphae in the cuticle and spores. X500.

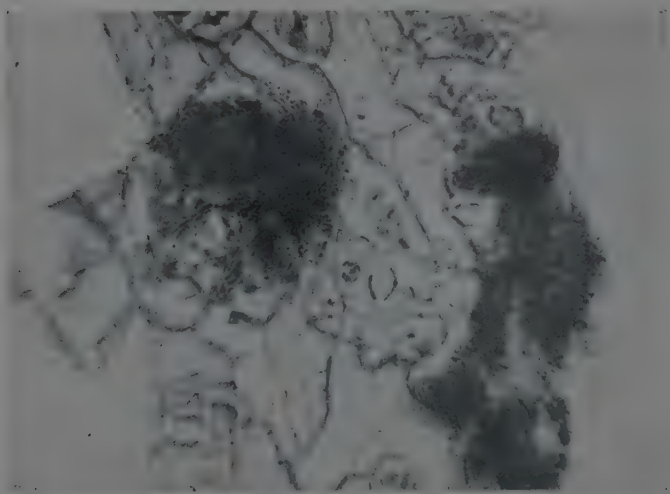

FIG. 4.—Surface view of epidermis showing hyphae forming two acervuli. X250

RESISTANCE

An unnamed cauliflower variety inoculated under the same conditions as Phenomenal Early failed to develop infection. This indicated the existence of resistant varieties, and suggested the necessity of classifying them. Twenty-three varieties of cauliflower and four of cabbage were tested for resistance to light-leaf-spot. Plants were raised in a cold frame, each variety being represented by one 6″ pot containing 24 plants. When six inches tall they were inoculated by means of a hand atomiser with a water suspension of spores from potato dextrose agar culture. After inoculation plants were placed in a cabinet for 24 hours at 18°c. and 100 per cent. relative humidity. They were then replaced in the cold frame for three weeks. At the end of this period spots were sufficiently well developed for differences in resistance to be determined. Two grades of infection were recorded ; viz. *Moderately susceptible*—with less than half the leaves infected and *Very susceptible*—with more than half the leaves infected. Results are shown in Table II.

TABLE II. VARIETAL RESISTANCE OF CAULIFLOWER AND CABBAGE SEEDLINGS TO *G. concentricum*

	Immune	Nil		
	Moderately Susceptible	Nil		
Cauliflower, Early Maturing	Very Susceptible	All the Year Round Early London Late Metropole Novo Phenomenal Early	Phenomenal Maincrop Snowball A. Snowball Southern Cross Super Snowball	Veitches Autumn Giant Veitches Self Protecting Walcheren
Cauliflower, Late Maturing (Broccoli)	Immune	Late Queen Penzance Roscoff No. 1	Roscoff No. 4 Satisfactory St. George	Snows Winter White
	Moderately Susceptible	Late White		
	Very Susceptible	Early White	Speeds Phenomenal	
Cabbage	Immune	Enfield Market		
	Moderately Susceptible	Early Market	Golden Acre	Jersey of Wakefield
	Very Susceptible	Nil		

To test resistance under field conditions inoculated cauliflower plants of eleven varieties were grown in the field during the summer months of December, January and February. Results were similar to those obtained in pots ; the different varieties showing the same relative resistance.

CONTROL

There is no record of light-leaf-spot becoming serious enough to warrant use of control measures. Immune varieties of cauliflowers and cabbages have been found and although the former are all late maturing varieties, these could be grown if the disease should assume economic importance.

ACKNOWLEDGMENT

The writer wishes to acknowledge the assistance given by Messrs. S. O. Gillard and T. C. R. Dawe, Horticulture Division, Department of Agriculture. Thanks are also due to the Agronomy Division, Department of Scientific and Industrial Research, for supplying seed.

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SULPHUR DIOXIDE AND STORAGE LIFE OF DEHYDRATED APPLES.

By J. L. MANGAN, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Palmerston North

(*Received for publication, 30th April, 1948*)

Summary

The retention of sulphur dioxide and storage life of dehydrated apples packed in standard cartons depends on the variety and storage temperature.

A cellophane wrap was found necessary for the effective retention of sulphur dioxide and rapid losses occur in packets of apples which have been partly used.

The loss of sulphur dioxide is roughly proportional to the titratable acidity and recommendations have been made that the acid varieties Ballarat and Washington should be marketed first, followed by Granny Smith, Statesman, Jonathan and Dunns.

INTRODUCTION

THE dehydration of apples in New Zealand, which developed during the war, has now been converted to normal commercial practice, the apple slices being placed on the market in ½ lb. cardboard cartons with a cellophane over-wrap. The present work was carried out to investigate the effects of variety, sulphur dioxide content and temperature on the storage life of dehydrated apples under these conditions, and in addition to determine whether the cellophane over-wrap improved the storage life of the product.

STORAGE AT ROOM TEMPERATURES AND AT 24°C.

The dried apples were obtained from the dehydration plant containing only a trace of sulphur dioxide. Prior to dehydration the apple slices had been treated with a sulphite dip to prevent browning during dehydration. The residual sulphur dioxide was determined and as in the commercial process, metabisulphite added to bring the sulphur dioxide content to the required levels. The varieties Jonathan, Dunns, Statesman, Washington, Ballarat and Granny Smith were obtained, and samples of each variety were brought to levels of 50, 100, 250, 500, 1,000

and 2,000 parts per million of sulphur dioxide. The ½ lb. samples were weighed out, sprinkled uniformly with the calculated weight of sodium metabisulphate, which was itself checked for purity, packed into cartons and sealed with cellophane (Sidac 300 M.S.T.). Six samples at each sulphur dioxide level were prepared for each variety, three for warm storage and three for room temperature storage. The warm store was a "Pinex" lined room fitted with a fan and maintained at 24°C. (75°F.) by thermostatic control. Room temperatures during the storage period were normally in the range 16°-20°C. but dropped considerably on frosty nights. Sulphur dioxide, colour formation and moisture content were determined on the samples during storage.

Sulphur dioxide was determined by the A.O.A.C. Monier-Williams method (1), and colour was measured by a colorimetric method as follows :—

10 g. of minced sample is soaked for 15 min. in 100 ml. of aqueous alcohol (2 alcohol : 1 water) and then blended in a Waring blendor. The macerate is filtered through fine glass wool and allowed to run until optically clear. A sample is then taken and the brown colour measured in a Coleman spectrophotometer using a wavelength of 425 mμ. The extinction value is a direct measure of the amount of browning which has occurred in the sample.

Moisture was determined by drying for six hours in high vacuum at 65°C.

It was intended to carry out two analyses on each packet, resealing with cellophane after the first determination. This procedure, however, was found to give consistently low results for the second analysis as is shown in the sulphur dioxide graphs for Jonathan and Dunns, and a corresponding abnormal increase in colour formation. It was therefore possible to carry out only one analysis per packet at two monthly intervals instead of the intended monthly analyses. This abnormal loss of sulphur dioxide could be due (1) to merely opening the packet or (2) to a more rapid loss of sulphur dioxide from a half filled packet than from a filled one. In a later experiment where a portion of a packet was packed tightly into a screwtopped jar, this loss was not observed and hence the second explanation is probably correct.

The figures for sulphur dioxide, colour and moisture content are given in Table I and for ease of comparison they are plotted in Figs. 1 to 12.

In general all the varieties stored at room temperatures kept remarkably well. By comparing extinction values with visual colour estimation it was found that an extinction value of .200 corresponds to a slight browning in the apples while a value of .250 corresponds to a definite brown tint, at which stage the appearance would be considered unattractive. To be on the safe side the end of the storage life was taken as the point where the colour graph passes through the extinction value of .200. It should be noted that the end of storage life was determined by the formation of colour in the dehydrated apple itself, and that cooking tests were not carried out to determine flavour and appearance after cooking. By this standard, all the varieties at all sulphur dioxide levels kept for at least three months at room temperatures. The colour graphs however varied greatly and were rising with different slopes. Thus in all the samples of Ballarat the colour graph reached the extinction value of .200 within the storage period. In the

higher sulphur dioxide levels of Washington and Granny Smith, however, the storage life was not completed in this time and an approximate value for the storage life was obtained by extrapolating the final section of the colour graph to the extinction value of .200. In the case of Dunns, and to a lesser extent Jonathans, colour formation was so slow that no estimate could be made of the storage life. Table II gives the storage life in days for each variety at each sulphur dioxide level.

TABLE I. STORAGE OF DEHYDRATED APPLES AT ROOM TEMPERATURES AND AT 24°C. AT DIFFERENT SULPHUR DIOXIDE LEVELS

Variety.	Time (days)	A. SO_2 p.p.m.	A. Colour.	B. SO_2 p.p.m.	B. Colour.	C. SO_2 p.p.m.	C. Colour.	D. SO_2 p.p.m.	D. Colour.	E. SO_2 p.p.m.	E. Colour.	F. SO_2 p.p.m.	F. Colour.	Moisture (per cent.)
Jonathan	0	80	.153	130	.153	280	.153	530	.153	1030	.153	2030	.153	19.2
(24°C.)	32	36	.177	22	.200	59	.208	210	—	518	—	1270	—	—
	60	29	.345	21	.270	24	.252	125	.200	348	.180	885	.138	—
	90	19	.295	19	.293	40	.265	115	.233	390	—	1015	—	—
	123	—	.400	—	.400	19	.323	64	.310	294	.220	796	.190	11.2
	158	6	.350	6	.380	15	.360	78	.385	298	.225	908	.160	11.3
Jonathan	0	80	.153	130	.153	280	.153	530	.153	1030	.153	2030	.153	19.2
(Room	41	24	.180	22	.166	113	.165	232	.145	640	.157	1382	.157	—
Temp.)	89	29	—	42	—	75	—	165	—	433	—	944	—	—
	122	19	.207	13	.187	46	.169	296	.177	513	.145	1088	.145	15.8
	186	3	.215	3	.200	46	.173	128	.155	336	.125	955	.115	15.5
Dunns	0	50	.120	100	.120	250	.120	500	.120	1000	.120	2000	.120	22
(24°C.)	34	35	.200	35	.200	57	.168	110	.126	539	.105	1065	.090	—
	63	10	.220	10	.237	25	.200	95	.180	310	—	800	—	—
	93	20	.260	22	.230	30	.230	82	.193	375	.138	942	.106	16.2
	153	3	.300	0	.305	22	.280	41	.220	198	.166	555	.130	12.7
Dunns	0	50	.120	100	.120	250	.120	500	.120	1000	.120	2000	.120	22
(Room	36	54	.120	54	.120	143	—	300	—	710	—	1524	—	—
Temp.)	64	12	—	16	—	93	—	207	—	480	—	1036		
	93	25	.143	132	.143	76	.130	210	.120	505	.120	1216	.120	20.2
	160	0	.152	0	.152	38	.140	107	.140	370	.095	840	.095	20.2
States-	0			155	.108	255	.108	505	.108	1005	.108	2005	.108	18.4
man	35			34	.174	66	.165	257	.137	626	.152	1500	.152	16.6
(24°C.)	93			16	.175	40	.162	146	.138	480	.138	1322	.100	15.8
	156			40	.250	34	.230	86	.215	375	.155	1126	.150	14.4
States-	0			155	.108	255	.108	505	.108	1005	.108	2005	.108	18.4
man	37			83	.140	120	.145	320	.120	625	.120	1352	.120	18.3
(Room	93			46	.120	78	.108	230	.102	598	.105	1350	.105	18.7
Temp.)	157			30	.200	55	.160	214	.140	542	.120	1233	.120	18.2
Washing-	0			116	.100	266	.100	516	.100	1016	.100	2016	.100	—
ton	36			11	.220	32	.190	155	.165	400	.150	970	.143	18.5
(24°C.)	92			6	.330	13	.310	43	.220	270	.177	632	—	17.1
	156			22	.510	25	.535	60	.390	153	.350	550	.180	14.8
Washing-	0			116	.100	266	.100	516	.100	1016	.100	2016	.100	—
ton	37			35	.162	73	.123	258	.123	530	—	1270	—	20.1
(Room	92			10	.170	46	.140	158	.135	403	.102	940	.097	19.8
Temp.)	157			6	.220	54	.220	102	.200	304	.145	820	.140	18.9
Ballarat	0	67	.135	117	.135	267	.135	517	.135	1017	.135	2017	.135	16.9
(24°C.)	34	22	.255	13	.290	26	.270	124	.230	386	.185	1183	.170	17.0
	100	36	.380	8	.375	30	.340	30	.325	214	.210	559	.130	15.5
	150	30	.640	10	.650	40	.620	34	.570	86	.489	382	.349	14.1
Ballarat	0	67	.135	117	.135	267	.135	517	.135	1017	.135	2017	.135	16.9
(Room	36	12	.190	12	.200	64		200	—	462	.153	1230	145	18.0
Temp.)	101	22	.190	12	.200	25	.150	102	.145	339	.125	838	.095	18.1
	153	10	.400	6	.380	22	.335	23	.290	215	.230	635	.200	17.8
Granny	0	30	.122	80	.122	230	.122	480	.122	980	.122	1980	.122	10.5
Smith	31	36	—	57	—	125	—	300	—	663	—	1336	—	12.0
(24°C.)	96	18	.200	12	.225	60	.185	246	.180	495	.150	1030	.120	—
	157	22	.370	27	.320	82	.280	148	.245	546	.210	942	.200	11.2
Granny	0	30	.122	80	.122	230	.122	480	.122	980	.122	1980	.122	10.5
Smith	31	37	—	65	—	125	—	310	—	528	—	1520	—	13.5
(Room	116	30	.155	45	.160	97	.155	218	.148	558	.125	958	.125	15.8
Temp.)	158	21	.250	11	.245	88	.230	179	.195	398	.180	1040	.175	16.8

(The vertical columns A, B, C, . . . are the SO_2 levels, 50, 100, 250, . . . p.p.m.)

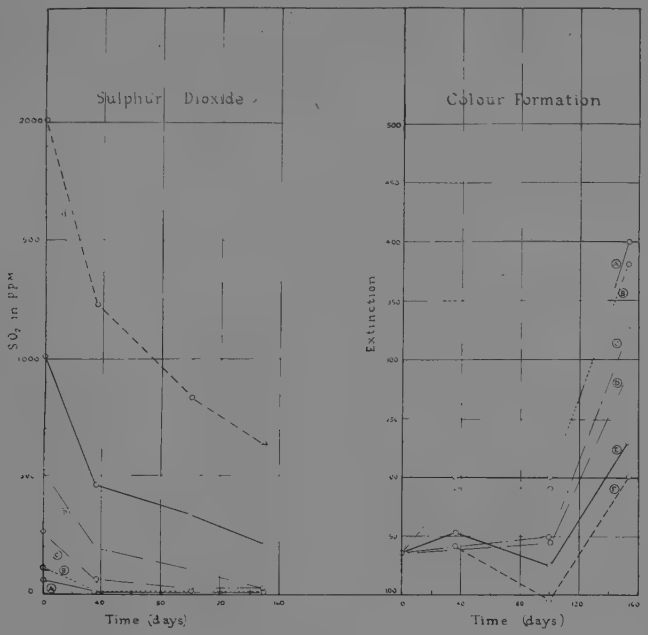

FIG. 1.—Storage of Ballarat apples at room temperatures.

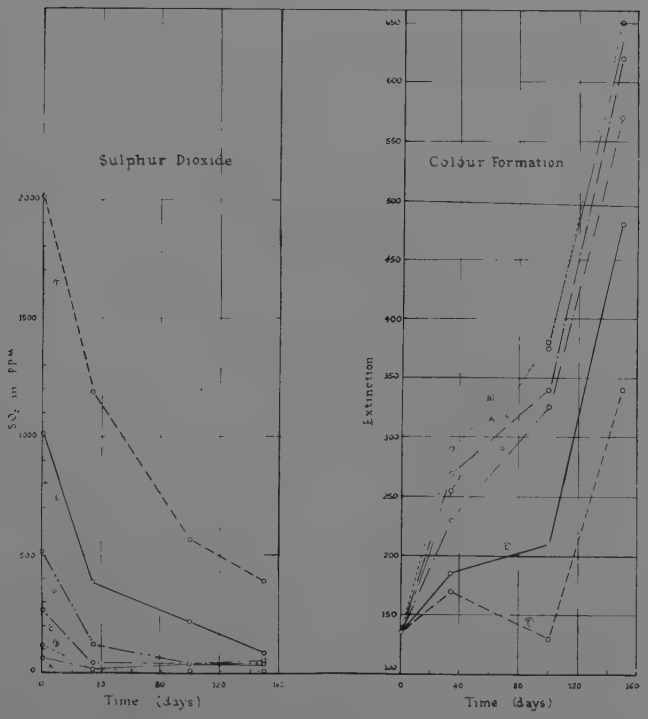

FIG. 2.—Storage of Ballarat apples at 24°C.

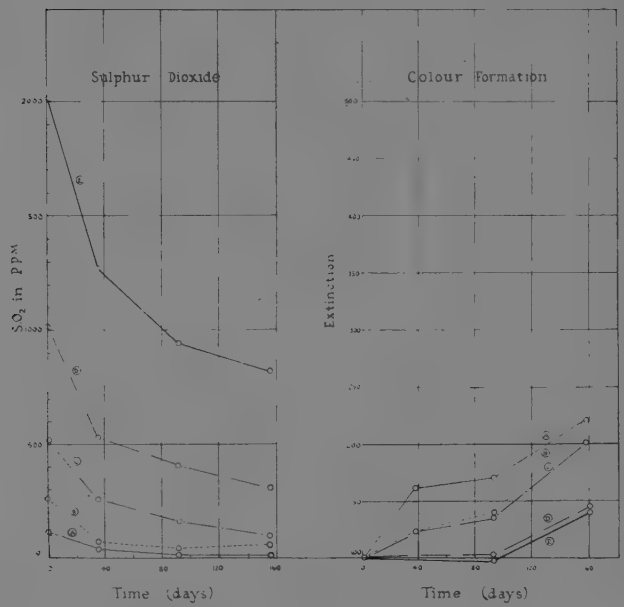

FIG. 3.—Storage of Washington apples at room temperatures.

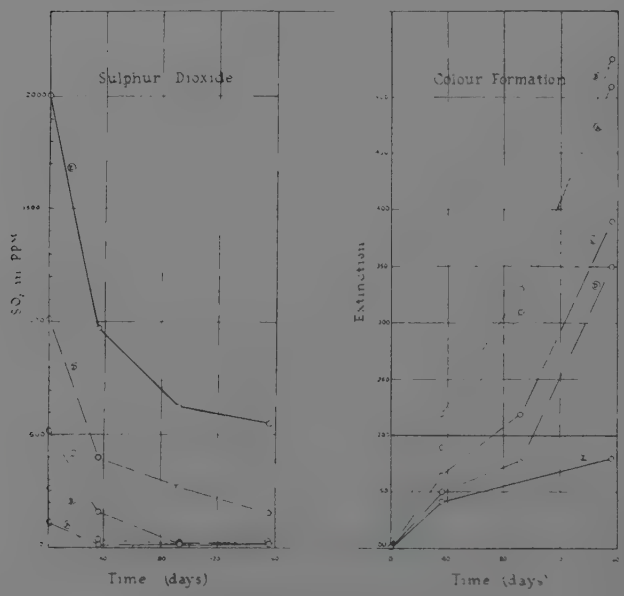

FIG. 4.—Storage of Washington apples at 24°C.

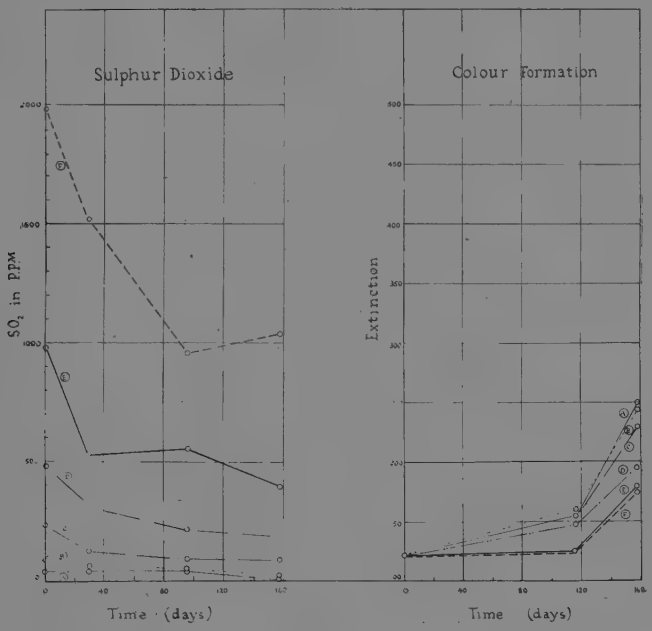

FIG. 5.—Storage of Granny Smith apples at room temperatures.

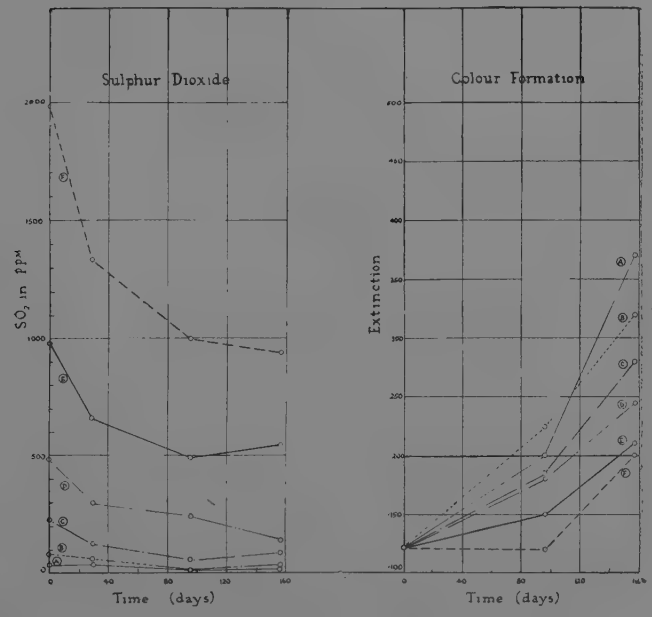

FIG. 6.—Storage of Granny Smith apples at 24°C.

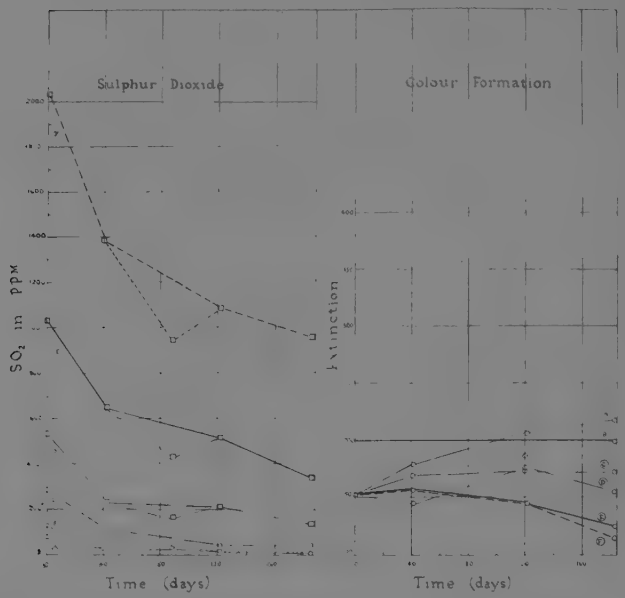

FIG. 7.—Storage of Jonathan apples at room temperatures.

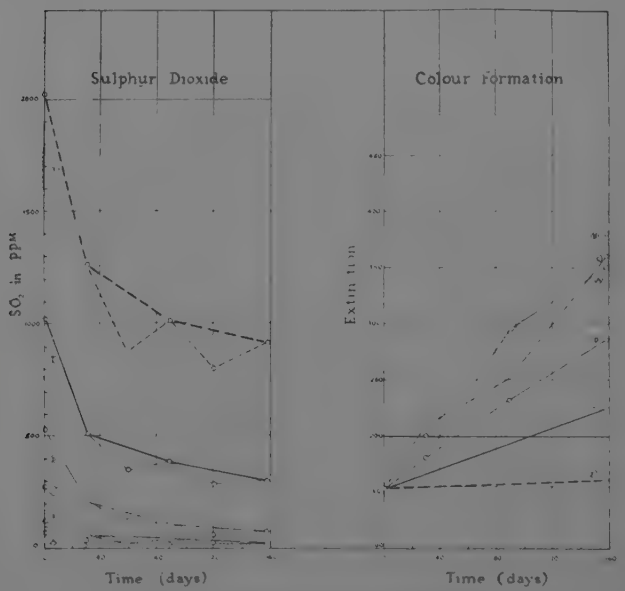

FIG. 8.—Storage of Jonathan apples at 24°C.

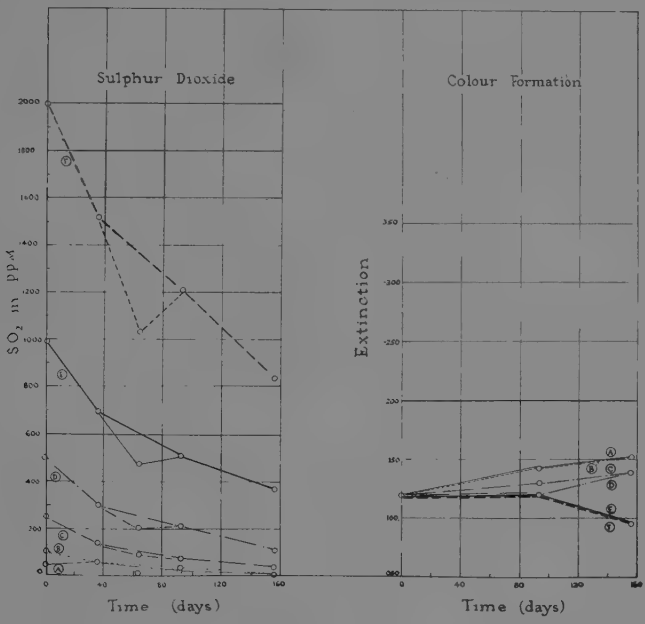

FIG. 9.—Storage of Dunn apples at room temperatures.

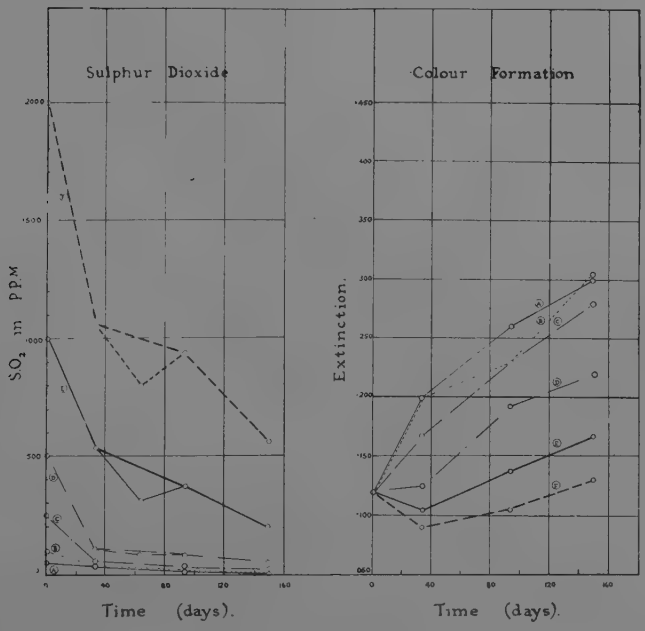

FIG. 10.—Storage of Dunn apples at 24°C.

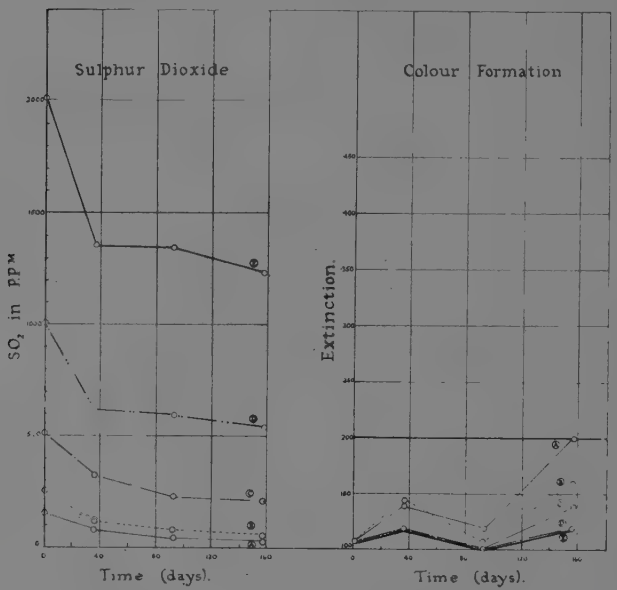

FIG. 11.—Storage of Statesman apples at room temperatures.

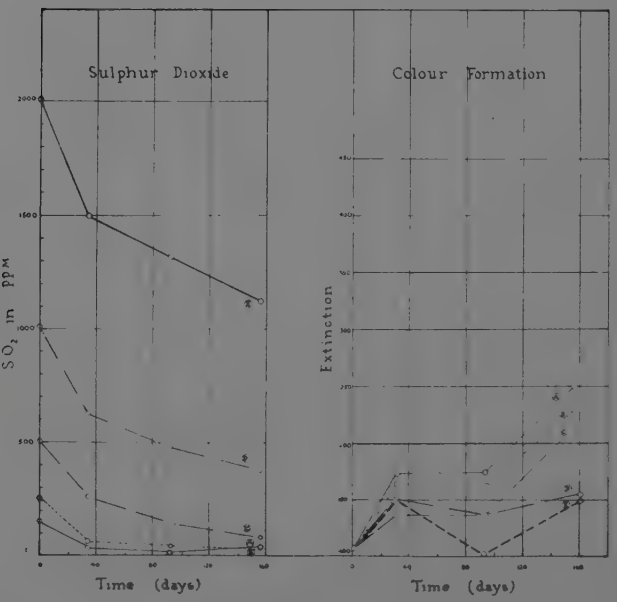

FIG. 12.—Storage of Statesman apples at 24°C.

TABLE II. STORAGE LIFE AT ROOM TEMPERATURES AT DIFFERENT SULPHUR DIOXIDE LEVELS

Variety.	50 p.p.m. SO_2.	100 p.p.m. SO_2.	250 p.p.m. SO_2.	500 p.p.m. SO_2.	1000 p.p.m. SO_2.	2000 p.p.m. SO_2.
Ballarat	104 days	100 days	116 days	120 days	136 days	154 days
Washington	— ,,	132 ,,	140 ,,	156 ,,	250* ,,	250* ,,
Granny Smith	136 ,,	136 ,,	142 ,,	162* ,,	165* ,,	180* ,,
Jonathan	96 ,,	176 ,,	v.l.	v.l.	v.l.	v.l.
Dunns	v.l.	v.l.	v.l.	v.l.	v.l.	v.l.
Statesman	—	156 ,,	202* ,,	260* ,,	v.l.	v.l.

NOTE : (1) Slight variations from these sulphur dioxide levels occur and can be seen in Table I.
(2) * Indicates figures determined by extrapolation.
(3) v.l. Indicates very long storage life.

Thus 500 parts per million of sulphur dioxide, which has been the recommended quantity, will keep Ballarats for four months, Washington five months, Granny Smith five and a half months, Statesman nine months and Jonathan and Dunns for a very considerable time at room temperatures. The addition of the maximum of 2,000 parts per million of sulphur dioxide to Ballarats however, only extends the life to five months and Granny Smith and Washington to an estimated six and eight months respectively.

The warm storage figures show the same effect in an exaggerated manner. On the warm storage figures the varieties can be classified into groups thus :—

A. *Ballarat and Washington.*

The colour graphs for these varieties are very steep and sulphur dioxide is lost very rapidly. By comparison of the graphs for storage at 24°c. and at room temperatures it is seen that the relatively small rise in temperature causes a much greater formation of colour and accelerates the loss of sulphur dioxide.

B. *Granny Smith, Jonathan and Dunns.*

The slope of the colour graphs in these varieties at 24°c. is moderate. Comparison of graphs shows that warm storage causes only a slight increase in the rate of loss of sulphur dioxide, but that colour formation is quite markedly increased.

C. *Statesman.*

The sulphur dioxide curves are not very different in warm storage and at room temperatures. The slope of the colour curves is small and increase in colour formation due to warm storage is not very great.

This grouping is in agreement with the titratable acidity figures which are given in Table III. These figures were not determined on the dehydrated apples as they came to hand since the pH was expected to be more important, but were obtained from fresh apples in 1945. Sturmer, a very important variety not included in these storage trials has a titratable acidity of 135, and from this it can be judged to lie between Granny Smith and Ballarat, with a short storage life probably approaching that of Ballarat and Washington. The pH seems to be of little significance.

TABLE III. TITRATABLE ACIDITY AND pH

Variety.	Millilitres 0.1N. NaOH/100 g. fresh tissue.	pH.
Washington	166	3.48
Ballarat	165	3.21
Granny Smith	79	3.54
Jonathan	77	3.47
Dunns	—	3.44
Statesman	64	3.90

The behaviour of Dunns is anomalous, since although at room temperature sulphur dioxide is lost more rapidly than in Statesman, colour formation is definitely less. In warm storage, however, it behaves normally. Sulphur dioxide is lost more rapidly than in Statesman while the rate of colour formation is so much greater that Dunns falls into the group with Jonathan and Granny Smith.

NOTE ON THE VALUE OF WARM STORAGE EXPERIMENTS

Generally speaking, warm storage of dehydrated apples at 24°C. gives a fair indication of the storage life to be expected in ordinary storage, in that the varieties can be classified into groups, but an exact relationship is not obvious. The " average slopes " of the colour graphs, i.e., the total vertical height divided by the corresponding horizontal distance, both measured in units of length, are given in Table IV.

TABLE IV. AVERAGE SLOPES OF THE COLOUR GRAPHS

SO_2 Level.	Ballarat.	Washington.	Granny Smith.	Jonathan.	Dunns.	Statesman
50 p.p.m.	2.74		1.28	1.17	0.99	
100 ,,	2.69	2.21	1.03	1.06	0.96	0.70
250 ,,	2.59	2.10	0.82	1.01	0.85	0.60
500 ,,	2.32	1.49	0.44	0.68	0.53	0.52
1000 ,,	1.84	1.28	0.46	0.38	0.24	0.22
2000 ,,	1.09	0.41	0.41	0.05	0.05	0.20

Within the range 50 to 500 parts per million of sulphur dioxide these values appear to fall fairly well into the three groups mentioned above. Thus group A has slope 3.0 to 1.5, group B 1.5 to 0.5 and group C 0.75 to 0.5. This does not hold for samples containing 1,000 or 2,000 parts per million of sulphur dioxide, while group C is not sharply separated from group B. A longer storage period, however, would probably have corrected these irregularities. It is considered from these results that storage at a higher storage temperature, say 37°C., for a shorter period would yield a similar but more clear cut grouping, and that after correlating with ordinary storage figures a rapid warm storage experiment could be used to predict the storage life of an unknown at ordinary temperatures.

THE EFFECT OF CELLOPHANE WRAP ON THE RETENTION OF SULPHUR DIOXIDE

The dried apple slices are marketed in ½ lb. standard cartons with a cellophane over-wrap, and although this is partly to improve the appearance of the package it was considered that the cellophane would probably retard the loss by diffusion of sulphur dioxide. The material used was " Sidac ", grade 300 M.S.T., which is heat sealing and partly

moisture-vapour proof. Six ½ lb. samples of Dunns were made to 500 parts per million of sulphur dioxide and packed in cartons, half of which were sealed in cellophane and the remainder left unwrapped. The samples were stored at room temperatures and sulphur dioxide determined at monthly intervals. The results are given in Table V., and it is seen that even at room temperatures the cellophane had a marked retarding effect on the loss of sulphur dioxide. Without the cellophane the apples lost 86 per cent. of their sulphur dioxide in the first month, after two months all sulphur dioxide had gone, and after three months the sample had begun to turn brown, the storage life probably being between three and four months. The wrapped samples on the other hand still retained 150 parts per million after three months, and from the results of the above storage trials a storage life of 9 months or more could be expected.

TABLE V. BARRIER EFFECT OF CELLOPHANE ON LOSS OF SULPHUR DIOXIDE

Time (days).	Cellophane Wrapped.		Unwrapped.	
	SO_2.	Colour.	SO_2.	Colour.
0	500 p.p.m.	White	500 p.p.m.	White
34	320 ,,	,,	70 ,,	,,
62	203 ,,	,,	10 ,,	,,
92	154 ,,	,,	10 ,,	Slight brown

The above results, which were obtained with the non-acid variety Dunns, would be even more striking in the case of acid varieties such as Ballarats or Sturmers.

LOSS OF SULPHUR DIOXIDE FROM A PARTLY USED PACKET OF DEHYDRATED APPLE SLICES

It was considered important to know for domestic purposes whether it was necessary to place any unused portion of a packet of apples in a closed container or whether it was satisfactory to leave it in the packet.

Three ½ lb. samples of Dunns were made to 500 parts per million of sulphur dioxide, packed in cartons, sealed with cellophane and left for one month at room temperatures to allow the sulphur dioxide to become evenly distributed. The packets were then opened, each was divided into two parts, one half being packed into a screw-topped jar (which was fairly tightly packed) and the other half was replaced in the packet which was closed but not wrapped with cellophane. Storage was continued at room temperatures and sulphur dioxide determined at monthly intervals. The results are expressed in Table VI

TABLE VI. LOSS OF SULPHUR DIOXIDE FROM AN OPENED PACKET OF APPLES

Time (days).	In screw-topped jar.	In cellophane wrapped packet.	In unwrapped packet.
0		500 p.p.m.	
34		320* ,,	
62	234 p.p.m.		62 p.p.m.
92	190 ,,		20 ,,
126	172 ,,		3 ,,

(* Figure assumed from previous experiment.)

As was expected the portion left in the packet lost sulphur dioxide very rapidly, while that in the jar retained it somewhat better than the unopened cellophane wrapped samples of the previous experiment. As in the previous experiment the results would be accentuated in the case of acid varieties of apples.

Recommendations

The results obtained in the investigations justify the following recommendations.

(1) The minimum initial sulphur dioxide content required to keep dehydrated Statesman, Jonathan and Dunn apples until new season's fruit is available is 500 parts per million.

(2) The minimum sulphur dioxide level for other varieties is 1,000 parts per million, but even at this level the storage life of Ballarat, Granny Smith and probably Sturmer apples is not likely to exceed 6 months.

(3) The order of marketing the dehydrated product should be Ballarat, Washington, Granny Smith, Statesman, Jonathan and Dunns. Although dehydrated apples of the Sturmer variety were not included in these trials it is considered that these should be marketed about the same time as the Granny Smith product.

(4) It is recommended that cartons be over-wrapped with a grade of cellophane which is impermeable to water vapour and to sulphur dioxide.

(5) It is suggested that the directions on the cartons should include a recommendation to the effect that if a portion of the contents of a carton are to be kept for some time, this should be transferred to a screw-topped jar or other air-tight container of suitable size.

Acknowledgments

This work was carried out for the Internal Marketing Division, and the general outline for the investigation was planned by Dr. B. W. Doak, Plant Chemistry Laboratory and Mr. L. W. Tiller, Fruit Research Officer. The writer wishes also to thank Dr. Doak for his interest in the work and for assistance in writing the manuscript. Thanks are also due to Mr. R. M. Greenwood for figures on titratable acidity of apples.

References

(1) Methods of Analysis — A.O.A.C. (6th Edition) p. 533.

TESTS WITH D.D.T. AND GAMMEXANE ON THE LARVAE OF A DERMESTID BEETLE (*ATTAGENUS* SP.), A PEST IN SOME NEW ZEALAND WOOLLEN MILLS

By R. A. Harrison, Assistant Entomologist, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 18th February, 1948*)

Summary

The larvae of a Dermestid beetle (*Attagenus* sp.) damages cops of spun yarn in some New Zealand woollen mills. Tests are described in which the toxicity of D.D.T. and Gammexane to these larvae is established.

It is shown that scoured wool impregnated with a solution of D.D.T. in acetone at rates of 2 per cent., 5 per cent. and 10 per cent. D.D.T. by weight of wool, caused mortalities of 28.1 per cent., 29.2 per cent. and 38.3 per cent. of larvae respectively after 18 days exposure and mortalities of 58.2 per cent., 81.7 per cent. and 82.5 per cent. respectively after 35 days exposure.

Treatment of scoured wool with an acetone solution of benzene hexachloride at the rate of 5 per cent. of the gamma isomer by weight of wool caused complete mortality of larvae within 18 days.

D.D.T. incorporated in a neatsfoot batching oil emulsion and applied to scoured wool at the rate of 0.57 per cent. D.D.T. by weight of wool gave an average mortality of 75.2 per cent. of larvae in one test of 17 days duration and 72.5 per cent. in a second test of 14 days duration.

Continued contact of larvae with D.D.T. is necessary to secure adequate control. The nature of the D.D.T. deposits on the wool and their significance in relation to mortality is discussed.

LARVAE of a Dermestid beetle (*Attagenus* sp.)* commonly called the "Woolly Bear" cause considerable damage in some New Zealand woollen mills to cops of spun yarn in store. Damage inflicted is characteristic in that larvae eat their way towards the centre of the cops and in doing so, weaken or break numerous parts of the thread, rendering it unusable. In this paper are described experiments to determine if treatment of scoured wool with D.D.T. or Gammexane would protect wool against these larvae.

METHODS AND RESULTS

It was first necessary to determine if D.D.T. and Gammexane are toxic to these Dermestid larvae. Once this was established it was then necessary to ascertain if the toxicant could be incorporated in one of the mill processes. Preliminary tests were therefore undertaken with treatments of wool using acetone solutions of D.D.T. and Gammexane, followed by tests with D.D.T. in a batching oil.

Wool used in the experiments was scoured fleece. *Attagenus* sp. larvae collected from damaged cops in a store room several days before the tests were commenced, were fed on scoured wool until required for the experiments. The D.D.T. used contained 99-100 per cent. para para isomer, while crude benzene hexachloride containing 13 per cent. of the gamma isomer was the source of Gammexane. The batching oil was neatsfoot oil.

All experiments were conducted in the laboratory in glass petri-dishes, 3 in. diameter and $\frac{5}{8}$ in. deep. In each dish approximately 0.6 g. of wool was placed, this being of such a bulk as to fill the dish and allow the lid to fit tightly. Twenty larvae of uniform size were placed in each dish; small larvae were not used. The petri dish containing wool and larvae was then placed in a larger dish, which acted as a trap for larvae which might escape and the whole left undisturbed in the laboratory.

Tests with Acetone Solutions.

Acetone solutions were used on the wool as follows: Four samples of wool, each 10 g. were taken from the scoured fleece and 50 ml. lots of acetone containing 0.2, 0.5, and 1.0 g. D.D.T. and 3.86 g. of crude benzene hexachloride were added to give 2 per cent, 5 per cent. and 10 per cent. D.D.T. and 5 per cent. Gammexane by weight respectively. The volume of acetone was sufficient to wet the wool thoroughly without leaving any residue unabsorbed. The acetone was allowed to evaporate immediately after application of the solution, evaporation being hastened by use of a small blower. Portions of each sample were then placed in petri dishes.

* Identified by the Commonwealth Institute of Entomology, London.

During treatment the solution tended to accumulate in the denser parts of the wool mass and to drain to the bottom as evaporation proceeded, with the result that the deposit of insecticide on the fibres was heavier in these parts than elsewhere. An effort to overcome this defect by teasing out the wool before addition of the solution was only partially successful. Because of this unevenness of deposit and because the 0.6 g. portions of the wool actually placed in the petri dishes were taken from those parts of the 10 g. samples which did not contain an obviously heavier deposit, the percentage of insecticide on the tested wool was probably below the figure aimed at.

Six replications of treatments and checks were included in the tests. Checks comprised untreated wool and wool soaked in acetone alone.

Larvae were placed in each dish on 12th September, 1946, and mortality counts were taken on 30th September and 17th October. When mortalities were being recorded it was observed that some of the larger larvae had pupated during the test period. Pupae were included in the count as live larvae. Results are given in Tables I and II.

TABLE I. EFFECT ON LARVAE OF *Attagenus* SP. OF D.D.T./ACETONE AND GAMMEXANE/ACETONE APPLIED TO SCOURED WOOL. 18 DAYS EXPOSURE.

	Check. Wool only	Check. Wool and Acetone only.	2 per cent. D.D.T.	5 per cent. D.D.T.	10 per cent. D.D.T.	5 per cent. Gamma-isomer.
Mean percentage mortality	2.6	1.8	28.1	29.2	38.3	100
Mean equivalent angle	7.1°	4.5°	31.4°	32.2°	37.1°	90.0°

Standard error = 3.8°
Difference required for significance at 5 per cent. level = 11.02°

TABLE II. EFFECT ON LARVAE OF *Attagenus* SP. OF D.D.T./ACETONE APPLIED TO SCOURED WOOL. 35 DAYS EXPOSURE

	Check. Wool only.	Check. Wool and acetone only.	2 per cent. D.D.T.	5 per cent. D.D.T.	10 per cent. D.D.T
Mean percentage mortality	4.6	6.9	58.2	81.7	82.5
Mean equivalent angle	9.8°	13.2°	49.9°	65.1°	66.8°

Standard error = 4.1°
Difference required for significance at 5 per cent. level = 11.9°

Tests with Batching Oil.

Tests using a neatsfoot oil emulsion containing D.D.T. were carried out after completion of the acetone solution trials. Neatsfoot oil is one of the common batching oils used in New Zealand mills and is frequently used in a formula which results in the wool containing approximately 6 per cent. of oil. In these tests a similar formula was used and the method of application to the wool was the same as that used in mills. The emulsion was prepared as follows:

2 ml. neatsfoot oil containing 8 per cent. w/v D.D.T.*
1 ml. emulsifier made by dissolving bar soap in water.
7 ml. water.

* This was a saturated solution of D.D.T.

This was heated to 120°F. and sprayed onto 1 oz. of wool by means of an atomizer. The treated wool contained 0.57 per cent. D.D.T. by weight. The wool was left undisturbed for several days to allow excess water to evaporate. Portions were then placed in petri dishes and larvae added. The experiment included six replications of treatment and checks, the latter consisting of scoured wool alone. Tests were commenced on 26th October, 1946, and mortality counts were made on 12th November. Results are recorded in Table III.

TABLE III. EFFECT ON LARVAE OF *Attagenus* SP. OF D.D.T./NEATSFOOT OIL EMULSION APPLIED TO SCOURED WOOL. 17 DAYS EXPOSURE

Replications.	Percentage Mortality.	
	Check.	0.57 per cent. D.D.T.
1	0	100
2	0	47.3
3	5.5	94.4
4	0	68.4
5	0	75.0
6	0	65.0
Mean	0.9	75.2

Tests with neatsfoot oil were repeated on 31st March, 1947, to check results of the previous experiment. On this occasion a test with wool treated with neatsfoot oil emulsion, but without D.D.T., was added. There were six replications of each treatment. Mortalities were recorded on 14th April, results being given in Table IV.

TABLE IV. EFFECT ON LARVAE OF *Attagenus* SP. OF D.D.T./NEATSFOOT OIL EMULSION APPLIED TO SCOURED WOOL. 14 DAYS EXPOSURE

	Check. Wool only.	Check. Wool and emulsion only.	0.57 per cent. D.D.T.
Mean percentage mortality	2.5	5.0	72.5
Mean equivalent angle	8.1°	12.6°	61.6°

Standard error = 4.6°
Difference required for significance at 5 per cent. level = 13.9°

After mortalities had been recorded all live larvae from the six dishes containing wool treated with D.D.T./neatsfoot oil emulsion were placed in another dish containing scoured wool only. Seven days later 18.2 per cent. of these larvae were dead and after $5\frac{1}{2}$ months the mortality was 45.4 per cent.

DISCUSSION

The toxicity of D.D.T. to *Attagenus* sp. larvae has been established in all tests. Results of the acetone solution trials (Tables I and II) show that at the level of significance stated there was no significant difference between the three D.D.T. treatments after the 18 day period; after 35 days, however, a significant difference was apparent between the 2 per cent. and 5 per cent. and 2 per cent. and 10 per cent. treatments, but not between the 5 per cent. and 10 per cent. treatments.

The tests with Gammexane have shown that it is highly toxic to the larvae, much more so than is D.D.T. at the same or double the dosage of active insecticidal material (Table I). Under conditions of the tests, however, it is possible that this insecticide exerted some fumigant action which increased the kill. An objectionable feature of the use of crude benzene hexachloride was the fact that the wool was stained a dull red. As this would be undesirable in mills, tests with this material were not carried further.

An examination of the mean percentage mortalities in Tables I and II in relation to the duration of the tests shows that the action of D.D.T. on these larvae when it is applied to wool in an acetone solution is comparatively slow. The maximum kill of all treatments was 82.5 per cent. after 35 days. This apparent slowness may be due to the fact that, when applied with acetone, D.D.T. is deposited in the form of coarse crystalline masses which adhere loosely to the fibres. The physical nature of the deposit possibly has some bearing on the relative slowness of the toxic action, as D.D.T. in large crystal form has been shown to have no marked lethal effect on bed bugs (*Cimex lectularius* L.) when compared with D.D.T. deposited as minute crystals (Barnes, 1945).

Results from the tests using D.D.T. in neatsfoot oil emulsion (Tables III and IV) show that D.D.T. in this form gave a more rapid kill of larvae than when deposited from an acetone solution. This can be accounted for by the fact that the oil solution of D.D.T. which remains on the fibres after the water has evaporated from the emulsion does not volatilise and leave crystals of D.D.T. to any extent. Consequently the larvae, when working their way through the wool, become coated with the solution. D.D.T. is thus brought into intimate contact with the entire body surface and being in an oil solution is more readily absorbed through the integument than when present in crystalline form.

That oil when used alone did not have any toxic effect on larvae under the conditions of the tests is shown in Table IV where there is no significant difference between the two sets of checks.

Continued contact with D.D.T. appears necessary for satisfactory results. It has been shown that after 14 days exposure to D.D.T. emulsion on wool, of larvae which were alive at the end of the period and which were transferred to wool uncontaminated with D.D.T., only 18.2 per cent. or 5 per cent. of the original total were dead after a further seven days. The amount of D.D.T. absorbed during the 14 days was not sufficient to cause death in all larvae as at 5½ months a percentage was still alive and these subsequently pupated and emerged as adults.

In the light of results obtained in these experiments, application of D.D.T. in neatsfoot oil emulsion offers a promising means of control of larvae in woollen mills. Further work is needed to determine whether D.D.T. in the oil will remain on the fibres in sufficient concentration to be toxic to larvae after the wool has been carded and spun into yarn.

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COPPER DEFICIENCY OF ONIONS GROWN ON PEAT. I. PRELIMINARY REPORT

By A. F. R. Adams, Canterbury Agricultural College, Lincoln, New Zealand

(*Received for publication, 23rd June, 1948*)

Summary

A preliminary account is given of a copper deficiency of vegetables, particularly onions, grown on an acid peat soil near Christchurch. A significant response to a foliar spray treatment using copper sulphate has been obtained. A more extensive trial is proceeding.

Introduction

Historical

The stimulating effect of copper on plant growth, particularly on peat soils, has been noted by many workers. Felix (1) obtained improved growth of plants by the application of copper sulphate, both as a soil amendment and as a foliar spray, and Allison, Bryan and Hunter (2) were able to produce crops on previously unproductive peat by the use of copper sulphate. Similarly Bryan (3) obtained greening in chlorotic leaves of plants from the Florida Everglades soil by treatment with solutions of copper and manganese salts. In Northern Europe, Ritzema (4) and Hudig, Meyer and Goodyk (5) showed that copper sulphate was effective in controlling "Reclamation disease" which occurred on soils largely rich in humus.

However, these experiments and many others, while indicating the beneficial effect of copper on the plant, did not establish final proof of its essentiality to plant growth. The first evidence in this direction was given by Sommer (6). Using specially purified salts she showed that tomato, sunflower and flax plants failed to make normal growth in the absence of copper. Under similar conditions Lipman and Mackinney (7) showed that barley was unable to produce seed. Since that time, solution culture work has shown the necessity of copper for the normal growth of a wide range of plants.

It is now generally accepted that copper should be placed in the category of essential elements.

The use of copper salts applied as sprays to the crop or as an application to the soil to correct deficiencies is now widely used in many areas in other countries, especially on market garden crops grown on peat soils.

To date there is no record in New Zealand of deficiencies of copper affecting plant growth, though Cunningham (8) has demonstrated the effectiveness of applications of copper sulphate in correcting peat scours in cattle and enzootic ataxia in sheep grazed on copper deficient pastures on peat soils in the Waikato and other areas of New Zealand.

Experimental

Although vegetables for the Christchurch market are grown in many areas, the production from the peats and peat loams round the Marsh-

land district represents a major portion of the total. Much of the most intensively farmed peat areas has been cropped for upwards of forty years but additional blocks have been cleared and developed within the last ten years.

On a visit in January, 1947, to a farm on one of the recently developed blocks of acid peat soil (pH 4.5—5.0, with 70 per cent. organic matter) it was noted that the crop of onions was very poor and showed many patches where the plants had made practically no growth and others where they had declined after approximately eight weeks' growth (4-6 inches).

The symptoms suggested the probability of trace nutrient deficiency. A trial area was marked off and replicated plots were given spray applications of the following elements : manganese, zinc, copper, molybdenum, boron, magnesium, nitrogen, phosphorus and potassium. At the time of application all the onions were in very poor condition, the majority showing the symptoms described later. The trial area was visited one month later and the following results noted.

With the exception of the copper treated plots, no visible improvement was apparent ; in fact, in most instances the plants had deteriorated. The two copper treated plots showed a marked improvement.* Though at the time of treatment the plants were dying back and in many instances were very nearly dead, they had made a remarkable recovery and considerable new growth was evident (Fig. 1).

FIG. 1.—Copper deficiency of onions.
Left, portion of control plot. Right, portion of copper treated plot.

* The mode of application of the copper was as follows :— One ounce of copper sulphate was dissolved in 2½ gallons of water, a wetting agent added and the solution watered directly on to the plants. This quantity was used on an area of 15 sq. yds

Fig. 2 shows typical onions from the copper treated and control plots one month after treatment. The marked response is clearly shown, both in foliage and in the development of the bulb and roots.

Fig. 2.—Copper deficiency of onions.
Left, copper treated onions one month after treatment.
Right, control. No copper

Symptoms of Copper Deficiency

The physiological symptoms of copper deficiency for some plants, such as cereals and citrus trees, have been fully described in the literature, but those for onions have received less attention from workers in the field. However, Harmer (9) quotes poorly coloured onions and tops dying back prematurely from the tips as indicative of copper deficiency and these symptoms are confirmed by Knott (10) and Muckenhirn (11). J. J. Skinner in Hambidge (12) lists the following symptoms as characteristic : leaves failing to maintain firmness, and foliage chlorotic with a bleached appearance ; while Brenchley (13) states that chlorosis of leaf tips is very usual, and cites poor growth, with many plants failing to reach maturity as other symptoms which sometimes occur in cases of copper deficiency of plants. The symptoms observed during the course of the trial agreed with those quoted above and can be summarized and extended as follows :

Leaves.

Somewhat paler than usual with some slight chlorotic mottling, accompanied by loss of turgor (the older leaves being most affected), from the tips downwards. These leaves later bend back, wither and die back to the point of bending.

Bulb and root development.

Bulbs poorly developed, the majority failing to mature, with many actually going back in development and finally withering. Root system very weak.

COPPER CONTENT

The above evidence for a deficiency of copper is further supported by analyses of the onions for copper content, using the method of Clare, Cunningham and Perrin (14). The copper contents of three samples of onions from the trial area and of one sample from the treated plots are given in Table I. Included also in this Table are figures for a normal onion crop grown on a different soil type and figures cited by other workers.

TABLE I. COPPER CONTENT OF ONIONS
(p.p.m. on moisture-free basis)

Untreated Onions.	Treated Onions.	Normal Onions.	Lindow, Elvehjem and Peterson (15).	Remington and Shiver (16).	Coleman and Ruprecht (17).
4.5*	7.1*	9.2†			
2.8		8.6	13.5†	11.5†	13–16†
3.2					

* Whole plants. † Bulb only.

Other crops, viz., lettuce and red beet, growing on similar soil, showed poor growth and it was thought probable that this was another manifestation of the same trouble. Carrots, swedes and potatoes appear to be less affected than are other vegetable crops.

A more extensive trial to measure the relative effectiveness of foliar spray and light and heavy soil dressings was laid down on this area in September, 1947, and work on this trial is proceeding. Marked yield responses to applications of copper sulphate have been obtained and it is proposed to deal fully with this work in a paper to be published later.

ACKNOWLEDGMENTS

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SPECTROPHOTOMETRIC DETERMINATION OF COBALT IN PASTURES AND ANIMAL TISSUES

By K. J. McNaught, Ruakura Animal Research Station, Department of Agriculture, Hamilton*

(*Received for publication, 23rd October, 1947*)

Summary

(1) A procedure for the preparation of solutions for spectrophotometric measurement of cobalt is described. Ether extraction of iron is necessary.

(2) Absorption spectra of the cobalt complex and the reagent, before and after nitric acid treatment, are presented.

(3) The data suggest that for direct application of spectrophotometric methods, measurements are most satisfactory at 540mμ, provided the solutions are shielded from daylight.

(4) For solutions freed from excess reagent by treatment with bromine-water measurements are best made at 480mμ. Special precautions to exclude daylight are unnecessary. Bromine-water treatment produces no marked change in the absorption spectrum of the cobalt complex.

Introduction

The main difficulties encountered in the visual measurement of the colour of the cobalt complex with nitroso R-salt (1) (2) result from the presence of the residual colour due to excess reagent. The partial destruction of the excess reagent by nitric acid introduces a very labile yellowish component, the intensity of which is affected by the amount of nitric acid used, the final boiling time, the volume of the final solution, the amount of buffer added or of salts present, the age of the solutions and the degree of exposure to sunlight.

Possible methods for eliminating these difficulties due to excess reagent are: (a) reduction in amount of reagent used, (b) elimination of the final nitric acid treatment, (c) complete destruction of the excess reagent colour, (d) use of spectrophotometric methods. The first three methods have been found to be unsatisfactory for the following reasons:—

* Now on staff of Soil Fertility Research Station, Hamilton.

(a) It is not safe to reduce the amount of reagent used, since (i) the interaction between cobalt and nitroso R-salt depends on an endothermic time reaction reaching equilibrium under the particular conditions employed, hence an excess of reagent is desirable to ensure equilibrium at very low cobalt levels; (ii) the test solutions contain ions which, from various evidence, (1) (3), appear to form comparatively stable complexes at the reactive pH's for the formation of the cobalt complex and, therefore, immobilize part of the reagent; (iii) reducing and oxidizing agents readily attack the reagent. Even the 1 ml. 5 per cent. nitric acid added to the solutions just prior to the colour development (2) oxidizes part of the reagent, as shown by its effect on the equilibrium colour intensity produced with a fixed amount of reagent by excess cobalt.

(b) It is not convenient to dispense with the final acid treatment as usually a solid phase separates from the test solutions at the reactive pH range and the excess nitric acid is required to give clear solutions. Possibly some other strong, but non-oxidizing acid, such as hydrochloric acid, may be suitable for this purpose, but the solutions will still contain an interfering yellowish colour due to unaltered excess reagent and will be unsuitable for visual matching without filters.

(c) Marston and Dewey's method (3) of destroying the excess reagent with bromine-water was applied, but traces of iron remaining in test solutions, even after ether extraction, were found to interfere at low cobalt levels by changing the colour from faint pink to orange, thus making visual matching impossible. Citrate or pyrophosphate failed to suppress the iron colour, even when added to the limits of solubility, probably because the solutions were so strongly acid. However, under good light conditions, the eye can usually match the colours readily and with satisfactory accuracy when the excess reagent colour is present. This is because the background colour, due to the excess reagent, is sufficiently intense to be unaffected by the presence of variable small amounts of iron as found in the normal method.

(d) As it is desirable to eliminate subjective methods in the measurements, particular attention has been devoted to spectrophotometric methods, with the results reported in this paper.

EXPERIMENTAL

Absorption spectra of pure solutions

Cobalt nitroso-R Complex.

Absorption curves obtained by means of the Hilger medium quartz spectrograph are shown in Fig. 1. The cobalt complex, in solutions containing no added nitric acid, shows a peak at about 410mμ (ϵ about 48,000), a minimum at 348mμ (ϵ = 28,000), a minor peak at 318mμ (ϵ 52,000), a minor minimum at about 302mμ (ϵ = 48,000) and beyond this the absorption increases rapidly to extremely high values in the far ultraviolet. When nitric acid is present in the amounts used in the normal method (1), a similar curve is obtained to 340mμ beyond which observations cannot be made owing to strong absorption by the nitric acid. The molecular extinction coefficient, ϵ, of the cobalt complex, deduced from absorption curves obtained with excess cobalt, excess reagent and reagent alone, is approximately 43,000 at the 410mμ peak. Observations at wave lengths longer than 440mμ were made on the Cenco-Sheard spectrophotelometer with 7mμ wave band.

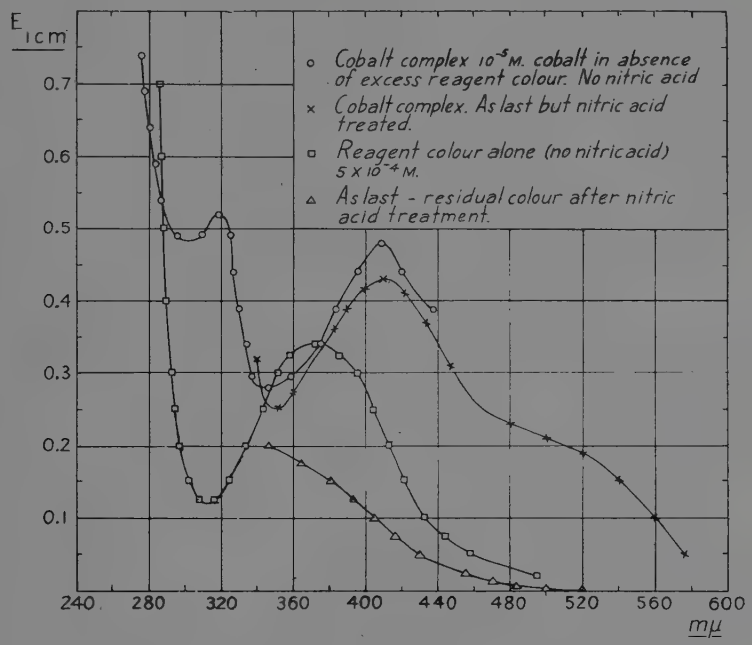

Fig. 1

Exact values for the molecular extinction coefficient of the cobalt complex have not been obtained partly because of difficulties experienced in the preparation of a reagent free from isomers and with a known amount of bound water. Although the kinetics of the reaction are imperfectly understood, it appears that the development of the cobalt complex depends on an equilibrium reaction, the complex being " fixed " by boiling with nitric acid. Different values for the apparent molecular extinction coefficient have been obtained at equilibrium according to the amount of excess reagent when the cobalt was kept constant or the amount of excess cobalt when the reagent was kept constant. When the reactant which was required in smallest amount, namely cobalt, was added in very great excess the equilibrium was shifted furthest towards a postulated 100 per cent. colour development. The complexity of the reaction may be still further accentuated if the suggestion (5) receives confirmation that part of the reagent, on the analogy of α -nitroso β -naphthol, is used up to oxidize the cobalt from the divalent to the trivalent form. However, this apparent need for quantities of reagent larger than the theoretical amount may merely be an equilibrium effect. Peroxide treatment of an acetic acid solution of cobalt, as used by Mayr and Feigl (6) for α -nitroso β -naphthol, failed to reduce the amount of reagent necessary for maximum colour development with a fixed amount of cobalt. In the tests carried out, more was needed, presumably because of partial destruction of the reagent by oxidation.

Reagent.

For this work the Hilger medium quartz spectrograph, the Cenco-

Sheard spectrophotelometer (7 to 15mμ wave bands) and the Coleman spectrophotometer (35mμ wave band) have been used, but the results shown in the figures were obtained with the first two instruments. The curves extending into the ultraviolet beyond 340mμ were obtained by the Hilger instrument. The wide band of 35mμ on the Coleman spectrophotometer precludes exact measurement of the extinction coefficient.

The absorption curve for the reagent, in the absence of nitric acid, shows a broad peak at 372mμ (ϵ = 6,800), a minimum at 312mμ (ϵ = 2,400) and beyond this sharply increases to high values in the far ultraviolet. After nitric acid treatment, the reagent peak at 372mμ is eliminated and the absorption steadily increases from 540mμ to the limit of observations at 340mμ. In such solutions daylight shifts the absorption by excess reagent strongly towards the longer wavelengths but beyond 540mμ this colour change is negligible (Fig. 2). This shows the calculated absorption curves for the amount of reagent used in the method and for a typical amount of cobalt, as found in pastures and animal tissues. The graph clearly shows the light labile nature of the excess reagent colour.

Cobalt complex in presence of excess reagent.

Reference to Fig. 2 shows that, under the conditions specified in the method (2), the excess reagent colour absorbs so strongly at the 410mμ peak as to render measurement at this wavelength impracticable with amounts of cobalt below about 10μg. At 560mμ the excess reagent colour shows very slight absorption, whereas the cobalt colour still absorbs appreciably, the extinction being about 23 per cent. of that at the 410mμ maximum. The effect of light on the excess reagent is particularly marked at the shorter wave lengths from about 520mμ and the absorp-

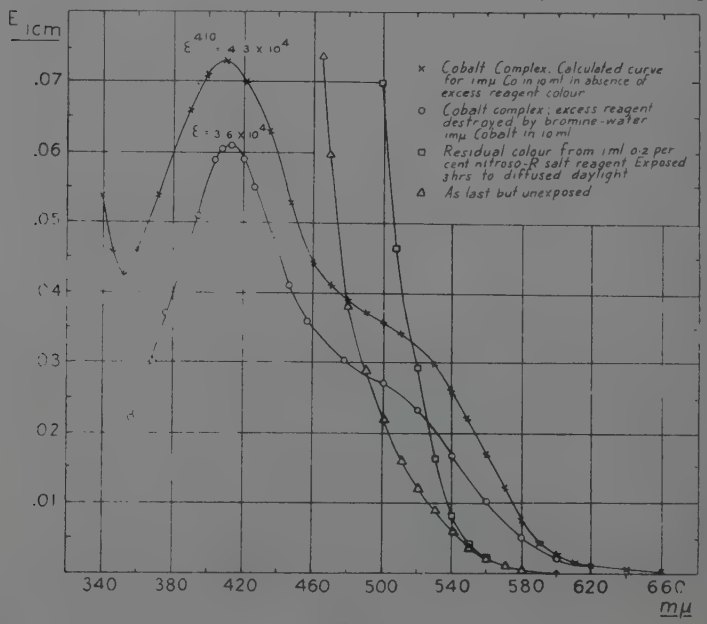

FIG. 2

tion curve rises sharply. Consequently the effective range over which estimation can safely be carried out with the spectrophotometer in this method is limited to about 520 to 580mμ. Only at wavelengths longer than 560mμ is absorption by the reagent unaffected by light. As the investigations into cobalt deficiency demand measurements at least down to 0.2μg. cobalt in 10 ml., 540mμ appears to be the most practicable wave length to use in the method outlined. The early model Cenco-Sheard spectrophotelometer with 1 cm. cells and the Coleman "Universal" photoelectric spectrophotometer were not quite as sensitive as desired, when used in the normal way. With the former instrument set at 540mμ and 10 to 15mμ wave band, scale readings had to be used between 90 and 100, outside the accurate range of the instrument. With the latter, measurements could be made at 540mμ (35mμ wave band) down towards 0.2μg. cobalt, provided the null deflection method was used. Greater accuracy should be possible with cells of longer light path or even by boosting the final colour intensity by addition of a known amount of cobalt, e.g. 1μg. to the test solutions just prior to the colour development. In all the above work shielding the solutions from daylight is necessary, more particularly if measurements are made at wave lengths shorter that 550mμ.

Solutions treated with bromine-water.

The similarity in absorption curves to those for untreated solutions containing excess cobalt (see Fig. 2) indicates that the bromine-water treatment produces no radical change in absorption spectrum of the cobalt complex over the range from 660 to 340mμ, though the molecular extinction coefficient appears to be reduced from about 43,000 to about 36,000 at the 410mμ peak.

Absorption spectra of pasture and liver ash solutions

Especially in the ultraviolet, the absorption spectra of pasture and liver ash test solutions were found to differ slightly from those of the standards, owing to traces of iron remaining even in ether extracted solutions.

The difference in absorption of light by ferric iron and by the cobalt complex was found to be sufficiently great, however, to enable estimations to be carried out between 460 and 560mμ, provided the bulk of the iron was removed by preliminary ether extraction. On the Coleman instrument results obtained with a typical amount of iron normally present in 10 g. "clean" pasture, namely 1mg., were about 13 per cent. high at the 1μg. cobalt level using 480mμ (35mμ band), and about 65 per cent. high at the 0.2μg. level. After ether extraction, the amount of iron remaining did not exceed 0.2 mg. At this level the interference was less than 3 per cent. for 1μg. cobalt and 13 per cent. for 0.2μg. cobalt, both these errors being within the apparent limits of accuracy of measurements at these levels. From the above considerations it appears that ether extraction of iron offers distinct advantages in the preparation of the test solutions, whether for direct spectrophotometric measurement or for measurement after destruction of excess reagent. In the latter method the wave-length of 480mμ appears to be the most satisfactory as the absorption curve of the cobalt complex is fairly flat and the absorption reasonably high.

Reference to Fig. 1 shows that, if some reliable treatment other than that with nitric acid, can be devised to give clear test solutions, it may

be possible to carry out direct measurements with instruments such as the Beckmann spectrophotometer at 312mμ. At this wave-length, in solutions containing no nitric acid, absorption by the excess reagent is at a minimum and the curve for the cobalt complex is comparatively flat.

Conclusions

The absorption spectra of the test solutions after ether extraction of iron do not differ significantly from those of pure standard solutions at the selected wave-lengths.

For direct application to the determination of the cobalt complex in the presence of the excess reagent colour, measurements are best made at about 540mμ, shielding the solutions from daylight. With longer wave-lengths interference by the excess reagent colour is much reduced, but any advantage from this is offset by the diminished absorption by the cobalt complex. For higher levels of cobalt than are normally found in pastures and animal tissues, shielding from daylight is unnecessary if readings are made between 560 and 600mμ, as the excess reagent colour is not affected by daylight over this wave band.

Measurement of the colour intensity in solutions freed from excess reagent by means of bromine-water is best made between 460 and 500mμ. As the excess reagent is absent, no special precautions to shield the solutions from daylight are needed but exposure to direct sunlight should be avoided. Shorter wave-lengths than 460mμ cannot safely be used, owing to increasing absorption by the traces of iron remaining in the solutions even after careful ether extraction. Even over the recommended range iron detectably interferes when its ratio to cobalt is greater than 100 : 1.

METHOD

On the basis of the above experimental data and conclusions, the following method has been developed.

Ashing:

Kidson and Askew's ashing method (4) is used.

Preparation of solutions:

For pastures a modified procedure is necessary to eliminate iron. The ash is taken up in 20 ml. constant boiling point (20 per cent.) hydrochloric acid, and the solution plus residues transferred to a beaker. The contents are evaporated fully to dryness on the sandbath and again taken up by boiling with 20 ml. 20 per cent. hydrochloric acid and filtered, washing thoroughly with hot water. Three drops of concentrated nitric acid are added and the solution is concentrated till pungent fumes of hydrochloric acid are evolved. The cooled solution is transferred to a separating funnel, washing in with 20 per cent. hydrochloric acid. Iron is separated by two extractions with ether. The solution is evaporated to small volume, 1 ml. concentrated nitric acid added to destroy organic matter introduced with the ether and the contents evaporated fully to dryness on the sand bath to eliminate the aqua regia. (*Note:* Solutions at the stage just prior to the colour development must be kept away from these fumes). A permanganate-like colour due to manganese usually develops under these conditions. Repeated evaporation to dryness with hydrochloric acid may be required to eliminate this compound, which, if not destroyed, may subsequently interfere by oxidizing part of the reagent. To the cooled residue are

added 10 to 15 ml. of water, followed by 0.5 ml. of 20 per cent. hydrochloric acid, etc., as in the normal method (2). For animal tissues no change in procedure is necessary.

Colour development is carried out by the method previously described (2).

Colour measurement:

Two procedures are available:

(a) Direct spectrophotometric measurement: In the presence of the excess reagent colour measurements are made at 540mμ, the solutions shielded from daylight.

(b) Spectrophotometric measurement after destruction of excess reagent: The excess reagent is destroyed by the method of Marston and Dewey (3); 1ml. 0.1N bromine-water is added to the hot solution after boiling with nitric acid. The solution is allowed to stand for 5 minutes and then boiled for 1 minute to eliminate excess bromine. Measurement of the colour intensity is made at 480mμ.

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SOIL DISINFECTION

VII. COMPARATIVE VALUE OF FORMALDEHYDE AND OF PARAFORMALDEHYDE IN CONTROL OF VERTICILLIUM-WILT

By H. JACKS, Plant Pathologist, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 9th May, 1947*)

Summary

Formaldehyde and paraformaldehyde were tested for control of verticillium-wilt of tomatoes.

Formaldehyde at a concentration of 0.8 per cent. (equivalent to 2 per cent. formalin solution), gave effective control of verticillium-wilt.

Paraformaldehyde was not as effective at equivalent dosages but gave satisfactory results at higher concentrations.

Paraformaldehyde caused less plant damage than did formaldehyde at equivalent dosages. Damage with either material was negligible, provided planting was delayed until 3 to 4 weeks after application.

INTRODUCTION

REPORTS received from growers suggested that the recommended formaldehyde treatment of 2-per cent. formalin (40 per cent. formaldehyde), applied at rate of 50 gallons to 15 sq. yd. of soil did not give effective control of verticillium-wilt (*Verticillium albo-atrum R and B*), in tomato crops. It was also reported that formation of paraformaldehyde precipitate which sometimes occurs during storage, resulted in a loss of efficiency and caused damage to plant growth. Investigations described in this paper were undertaken to ascertain the comparative toxicity of formaldehyde and paraformaldehyde to verticillium-wilt of tomatoes and to determine their effect on plant growth.

METHOD OF INOCULATION OF SOIL

Isolations from diseased plants were cultured on prune agar, transferred on to potato dextrose agar and finally grown on a media designed for easy mixing with soil. The latter media was prepared by mixing one part of oatmeal with 4 parts of sand. This mixture was placed in deep petri dishes at 3 oz. per dish, moistened and autoclaved for 2 hours at 15 lb. pressure. Dishes were left to cool, inoculated with culture and kept in an incubator at 25°C. until such time as the fungus had grown throughout the media. This was completed 25 days after inoculation. Steam sterilized potting soil was infected by mixing 6 dishes of inoculum with each cubic foot of soil. This was left for three weeks to allow the fungus to spread throughout the soil volume and, before treatment, was placed into boxes each of $\frac{1}{8}$ cu. ft. capacity.

MATERIAL AND METHOD

Paraformaldehyde supplied in compressed tablets was ground into a fine powder and dissolved in a known volume of warm water. Formalin (40 per cent. formaldehyde) and paraformaldehyde solutions were watered on to the soil at the rate of $\frac{1}{2}$ gallon per box and in proportions listed in Table I. The same quantity of water only, was applied to checks. Treatments were replicated four times.

COMPARATIVE EFFECT OF FORMALDEHYDE AND PARAFORMALDEHYDE

Soil in boxes was treated on 18th September, 1945, planted on 9th October with 24 Break O'Day tomato plants per box and results were recorded on 16th December.

Infected plants showed stunted growth, discoloration of vascular tissues and yellowing followed by wilting of lower leaves. Results recorded as percentage infection and weight of aerial portion of plants are given in Table I.

TABLE I. EFFICACY OF DIFFERENT CONCENTRATIONS OF FORMALDEHYDE AND PARAFORMALDEHYDE IN CONTROL OF VERTICILLIUM-WILT OF TOMATOES

Treatments carried out on soil held in boxes. Results from four replications of 24 plants each set out 3 weeks after treatment.

	FORMALDEHYDE.		PARAFORMALDEHYDE.	
Percentage Concentration.	Av. Per cent. Infection.*	Mean Weight of Plants. (grams)	Av. Per cent. Infection.*	Mean Weight of Plants. (grams)
0.0	91.66	9.52	91.66	9.52
0.1	59.74	13.62	65.70	12.17
0.2	41.40	13.20	61.46	9.89
0.4	39.37	11.93	51.04	10.97
0.5	12.46	11.04	27.70	11.56
0.8	3.12	15.05	25.00	13.84
1.6	0.00	6.62	5.49	12.71
3.2	0.00	6.12	0.00	7.56
Standard Error.	5.06	2.40	6.55	0.85
Difference Required for Significance at 5 per cent. level.	14.73	7.00	19.09	2.60

* Re-isolations made from vascular tissues of infected plants produced cultures of *Verticillium albo-atrum* in every case.

All treatments gave significant reduction of the disease when compared with untreated soil, formaldehyde at 0.8 per cent. and over and paraformaldehyde at 1.6 per cent. and over giving satisfactory control. Although differences in plant weight did not reach significance at 5 per cent. level, results suggest that formaldehyde at 1.6 and 3.2 per cent. and paraformaldehyde at 3.2 per cent. had a detrimental effect on plant growth.

TABLE II. MORTALITY OF TOMATO SEEDLINGS IN SOIL TREATED WITH DIFFERENT CONCENTRATIONS OF FORMALDEHYDE AND PARAFORMALDEHYDE AND PLANTED 10, 15, 20 AND 25 DAYS AFTER TREATMENT. RECORDS FROM 3 REPLICATIONS OF 36 PLANTS EACH

Percentage Mortality in Plants.

	FORMALDEHYDE.				PARAFORMALDEHYDE.			
	Period Between Treatment and Planting.				Period Between Treatment and Planting.			
Percentage Concentration.	10 Days.	15 Days.	20 Days.	25 Days.	10 Days.	15 Days.	20 Days.	25 Days.
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	9.37	4.17	1.04	0.00	2.08	1.04	0.00	0.00
0.8	41.67	7.28	1.38	0.00	4.16	2.18	0.00	0.00
1.6	100.00	55.21	27.08	2.08	7.29	3.25	0.00	0.00
3.2	100.00	84.37	30.21	3.12	98.96	31.25	8.33	5.21

EFFECTS OF FORMALDEHYDE AND PARAFORMALDEHYDE ON GERMINATION AND PLANT GROWTH

Boxes containing steam disinfected soil were treated with solutions of formaldehyde or paraformaldehyde at concentrations of 0.4, 0.5,

0.8 and 1.6 per cent. The soil was in a suitable condition for sowing 14 days after treatment and 500 tomato seeds were then sown in each box. All treatments were replicated three times. The number of seedlings that emerged was recorded after a period of 16 days. Viability of tomato seed was not affected by the treatments and resultant seedling growth was more vigorous than in untreated soil. Germination of seed sown in the higher concentrations (0.8 and 1.6 per cent.) of both materials was delayed by 2 to 3 days.

Boxes treated with the various concentrations of formaldehyde and paraformaldehyde were planted with 36 Potentate tomato seedlings at 10, 15, 20 and 25 days after application of solutions. Records of plants injured by residual effects of treatments were taken after 5 days (see Table II).

Injury to plants occurred in soil treated with concentrations higher than 0.4 per cent., but paraformaldehyde permitted earlier planting of soil than formaldehyde. In all cases soil was reasonably safe for planting 3 to 4 weeks after treatment.

DISCUSSION

Concentrations of formaldehyde at 0.8 per cent. and over gave satisfactory control of the fungus. Paraformaldehyde at twice the strength of formaldehyde solutions gave approximately equivalent results. Soil treated with paraformaldehyde solutions could be planted one week earlier than soil treated with equal dosages of formaldehyde. Neither material damaged plants set out 3 to 4 weeks after treatment.

SOIL DISINFECTION VIII. CHEMICAL CONTROL OF VERTICILLIUM-WILT OF TOMATOES

By H. JACKS, Plant Pathologist, Plant Diseases Division, Department of Scientific and Industrial Research

(*Received for publication, 17th July, 1947*)

Summary

Experiments on control of verticillium-wilt of tomatoes by soil treatments showed that:—

(1) Chloropicrin and formalin gave satisfactory control both in potting soil and in glasshouses.

(2) Carbon disulphide, D-D, Iscobromes I and II were of value in reducing incidence of the disease.

(3) Chloropicrin, D-D, carbon disulphide and Iscobromes I and II applied as emulsions to soil in boxes, gave better control than application of concentrated fumigants to soil held in gastight containers.

(4) Some fumigants gave better control when applied as mixtures.

INTRODUCTION

INVESTIGATIONS were carried out to ascertain the efficacy of soil fumigants in controlling verticillium-wilt of tomatoes (*Verticillium dahliae* Kleb).

Treatments were applied either to soils artifically infected or to those which had previously carried diseased crops.

Trials described in this paper cover investigations on control of verticillium-wilt by soil fumigants. Effects on plant growth and yield of tomatoes are also recorded.

MATERIALS AND METHODS

Composition of materials used and method of preparation of emulsions have been given in earlier papers (Jacks, 1946; 1947). Methods of applying materials were similar to those previously reported (Jacks, 1945 A; 1945 B). Dosage rates are given in the tables. Preparation of artificially inoculated soil has been described previously (Jacks, 1947).

The relative merits of fumigants were determined by (a) the presence or absence of fungus in vascular tissues, (b) the top weight of tomato seedlings, and (c) fruit yield of first five trusses.

Effects of chloropicrin on control of verticillium-wilt and yield of tomatoes

A. Applied to potting soil

Infected potting soil, sufficient for four boxes (dimensions 12 in. x 18 in. x 6 in.), was treated with chloropicrin at 5 ml. per cu. ft. and held for 48 hours in closed containers. The soil was then transferred to the boxes and 14 days after treatment each of these was planted with 24 Kondine tomato plants.

Results.—Records taken 14 weeks after planting showed 87.25 per cent. infected plants in untreated soil and 100 per cent. healthy plants in chloropicrin treatment. Plants in the checks became stunted and wilted at the tops, followed later by yellowing and wilting of bottom leaves. Those in treated soil remained healthy and produced good growth.

B. Applied to soil in situ

Chloropicrin was applied to soil in a commercial glasshouse in which the previous crop had shown approximately 25 per cent. infected plants. The material was injected at the rate of 2 ml. per sq. ft. to a depth of 5 in. Seven days after treatment 72 Potentate tomatoes were set out in each of six treated and six untreated plots.

Results.—The short period allowed for aeration of the soil caused a slight check in the growth of plants from residual chloropicrin, but recovery was complete after two weeks. Differences in growth between plants in treated and untreated soil were not apparent for the first two months. Later it became necessary to replace some wilted plants in untreated plots. Final records showed 48.5 per cent. infection in untreated plots, with an average yield of 4.9 lb. of fruit per plant, while records of treated plots showed 6.2 per cent. infection and 7 lb. of fruit per plant. In this experiment chloropicrin failed to give the complete control of verticillium-wilt obtained in a previous trial (Jacks, 1945), but nevertheless gave an increase in yield and considerably reduced incidence of the disease.

Effects of chloropicrin, D-D and formalin on control of verticillium-wilt and yield of tomatoes

Light volcanic loam in a glasshouse was artificially infected with cultures of *Verticillium dahliae*. The area was divided into 16 plots of 110 sq. ft. each, which were separated by asbestos boards sunk to a depth of 14 in. Formalin solutions were applied to the soil surface with a watering can, while fumigants were injected 5 in. deep. Treatments were applied on 22nd June, 1945, plots being randomized and replicated four times. Thirty-six Potentate tomato plants were set out in each plot on 12th July and harvesting records were completed by 4th February, 1946.

In the following season (1946), the experiment was repeated in the same house. The soil was again infected artificially and treatments were applied six weeks later. Crop yields were not recorded but degree of infection was determined by examination of vascular tissues in November, 1946. Results of trials are given in Table I.

TABLE I. EFFECT OF CHLOROPICRIN, D-D AND FORMALIN IN CONTROLLING VERTICILLIUM-WILT OF TOMATOES AND ON THE WEIGHT OF FRUIT PER PLANT

Treatment	Quantities per sq. ft. (ml.).	Season 1945. Mean percentage infected plants.	Season 1945. Mean weight of fruit per plant (Pounds).	Season 1946. Mean percentage infected plants.
Check	0.0	45.55	5.68	62.49
Chloropicrin	2.0	7.63	8.19	6.10
D-D	2.0	18.72	6.99	23.79
Formalin	33.6	15.80	6.01	8.51
Difference required for Significance at 5 per cent. level		11.43	1.84	11.25
Standard error		3.57	0.57	3.52

Results.—In 1945, height of tomatoes was even throughout the glasshouse for the first two months, after which chloropicrin treatment showed slightly better growth. All treatments gave an increase in yield over checks but only in the case of chloropicrin was this increase statistically significant. In both years, treatments gave significant reduction of infection, with chloropicrin giving most effective control. In both years, dry conditions at time of application affected the dispersion of formalin solutions, thus reducing efficacy of the fumigant in controllling the disease.

Effects of chloropicrin, D-D, carbon disulphide and iscobromes I and II on control of verticillium-wilt and growth of tomato seedlings

Two experiments were carried out (a) to determine comparative effects of concentrates and (b) to determine effects of the same fumigants applied in emulsified form.

Expt. (a). Application of concentrates

Infected potting soil, in sufficient quantity to provide four replications per treatment, was treated in air-tight containers and transferred to boxes after 48 hours. Ten days after treatment 24 Kondine tomatoes were planted in each box. Records of infection and weight of aerial parts of plants were taken after ten weeks and are given in Table II.

Results.—Plant injury appeared within 24 hours of planting, percentage mortality of seedlings being given in Table II. Further injury occurred in the next four days, i.e. 15 days after treatment, after which the fumigants had no further effect on seedling mortality.

TABLE II. EFFECTS OF SOIL FUMIGATION WITH CHLOROPICRIN, D-D, CARBON DISULPHIDE AND ISCOBROMES I AND II ON CONTROL OF VERTICILLIUM-WILT, WEIGHT OF TOMATO SEEDLINGS AND PLANT GROWTH

Treatment.	Quantities per cu. ft. (ml.).	Mean Percentage infected plants.	Mean weight of aerial parts of plants (g.).	Percentage mortality after treatment.	
				11 days.	15 days.
Check	0.0	96.87	10.33	0.0	0.0
Chloropicrin	6.0	0.00	19.44	1.1	0.3
D-D	6.0	66.66	12.53	4.3	1.8
Carbon disulphide	15.0	56.24	11.23	0.3	0.0
Iscobrome I*	6.0	68.74	13.03	4.1	2.4
Iscobrome II**	6.0	51.04	12.46	2.6	2.4
Difference required for significance at 5 per cent. level		17.80	3.08		
Standard error		6.28	1.04		

* Iscobrome I: 15 per cent. methyl bromide and 85 per cent. xylol.

** Iscobrome II: 25 per cent. chloropicrin, 15 per cent. methyl bromide and 60 per cent. xylol.

Chloropicrin gave significant improvements in disease control and increased weight of plants when compared with other treatments. Carbon disulphide, D-D and iscobromes I and II gave signficant reducton of infection as compared with checks. Although these materials increased plant weight, only iscobrome I gave results closely approaching significance.

Expt. (b). Application in emulsified form

Emulsions prepared with Wetsit in water were applied to infected potting soil held in boxes (dimensions 12 in. x 18 in. x 4 in.), at rates shown in Table III. Ten days later 24 Kondine tomato seedlings were planted in each box. Degree of infection and aerial weight of plants were recorded after 73 days.

TABLE III. EFFECT OF CHLOROPICRIN, D-D, CARBON DISULPHIDE AND ISCOBROMES I AND II, APPLIED IN EMULSIFIED FORM, ON CONTROL OF VERTICILLIUM-WILT AND WEIGHT OF TOP GROWTH OF TOMATO SEEDLINGS

Treatments.	Quantities in ml. applied with 1 gal. water to each cu. ft. of soil.	Mean percentage infected plants.	Mean weight of aerial parts of plants (g.).
Check	0.0	90.08	16.79
Chloropicrin	18.0	1.04	19.67
D-D	18.0	4.58	12.41
Carbon disulphide	45.0	1.04	10.29
Iscobrome I	18.0	4.21	12.86
Iscobrome II	18.0	0.00	12.35
Difference required for significance at 5 per cent. level		6.76	5.04
Standard error		2.28	1.70

Results.—All treatments gave significant reduction in infection. With the exception of chloropicrin, treatments reduced growth due possibly to the short interval between application of fumigants and date of planting.

Effects of chloropicrin, iscobrome II and mixtures of chloropicrin with D-D and of chloropicrin with iscobrome II on control of verticillium-wilt and on crop yields

Soil under glass which had previously grown an infected crop was treated with choloropicrin, iscobrome II, a 1:1 mixture of chloropicrin and D-D and a 2:1 mixture of iscobrome II and chloropicrin. Eighteen Potentate tomato plants per plot were set out in July, 1946, there being three replications of each treatment. Yield records from the first five trusses were completed in February, 1947.

TABLE IV. EFFECT OF CHLOROPICRIN, ISCOBROME II, A 1 : 1 MIXTURE OF CHLOROPICRIN AND D-D AND A 2 : 1 MIXTURE OF ISCOBROME II AND CHLOROPICRIN APPLIED TO SOIL IN GLASSHOUSE, ON CONTROL OF VERTICILLIUM-WILT AND YIELD OF FRUIT PER PLANT

Treatments.	Quantities per sq. ft. (ml.).	Mean percentage infected plants.	Mean weight of fruit per plant (Pounds).
Check	0.0	67.00	2.57
Chloropicrin	2.0	20.00	5.04
Iscobrome II	3.0	15.50	3.81
Chloropicrin and D-D (1 : 1)	2.0	8.33	5.17
Chloropicrin and Iscobrome II (1 : 2)	3.0	4.17	5.08
Difference required for significance at 5 per cent. level		20.40	1.16
Standard error		6.47	0.37

Results.—Treatments, as compared with checks, gave significant reduction in infection and increase in crop yield. Crop yield from iscobrome II was significantly less than from other materials. Mixtures gave improved control of the disease as compared with pure materials, although differences between fumigants were not significant.

DISCUSSION OF RESULTS

Of fumigants tested, chloropicrin gave the most consistent results in control of verticillium-wilt. It also improved growth and increased crop yield. Control of the disease was not always complete and results suggest that increased efficiency would be obtained by using higher dosages. Application of higher dosages, however, may not necessarily secure increases of crop yields. Plant damage occurred where a short interval was allowed between treatment and planting. Effect of residual toxicity in chloropicrin treated soil, was, however, less evident than in other materials.

Tests with formalin were not adequate. The soil was dry at the time of application and this condition affected the dispersion of the liquid.

Control of the disease was therefore less effective than would be expected under more favourable conditions of application.

D-D, carbon disulphide and iscobromes I and II gave relatively poor control of verticillium-wilt at dosages tested. Iscobrome II was the most effective of these materials. Further experiments with the different fumigants, are necessary to ascertain the possibility of obtaining economic control by application of higher dosages. Emulsified fumigants brought about results superior to those obtained by concentrates and this method of application will be investigated further.

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SOIL DISINFECTION. IX. CONTROL OF EELWORM IN OUTDOOR SOIL

By H. JACKS, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 7th August, 1947*)

Summary

In an experiment on the control of eelworm in heavily infested outdoor soil, chloropicrin and D-D applied at the rate of 3 ml. per sq. ft. gave almost complete control, while iscobrome II at the same dosage markedly reduced infestation.

Chloropicrin and iscobrome II also increased the yield of tomatoes, D-D just failing to give significant results.

Iscobrome I at the same rate of application and carbon disulphide at twice this dosage neither controlled eelworm nor increased yield.

All these fumigants significantly reduced weed population, chloropicrin giving the best control.

INTRODUCTION

EXPERIMENTS described in the present series of papers have been concerned with the application of fumigants to potting soils and glasshouse soils treated *in situ*. The need for disinfection also occurs in outdoor soils and an account of the treatment of an area of soil heavily infested with eelworm (*Heterodera marioni* (Cornu) Goodey) is given in this paper.

METHOD

For the purpose of this experiment, an area which in the previous year had carried a crop of tomatoes heavily infested with eelworm was divided into 24 plots, each 24 sq. ft. in area. To avoid spread of infestation and diffusion of fumigants, plots were separated by asbestos boards sunk to a depth of 15 inches.

Treatments included chloropicrin, D-D, carbon disulphide, iscobrome I and iscobrome II. Materials were applied on 20th October, 1946, four plots being treated with each and a similar number left untreated to serve as checks. Before treatment half a gallon of water per square yard was applied to each plot. The fumigants were then injected into the soil to a depth of 5 inches at rates given in Table I. The instrument used for application of fumigants was that described by Jacks and Wright (1946). To reduce loss of fumigants by volatilization, holes made by the injector were tamped with soil and each plot was given a water seal of one gallon per square yard. Soil temperature at the time of application was 20°C. and total soil moisture 15 per cent. Four days after treatment the soil was forked over to assist escape of residual gases. On 9th November, 1946, nine tomato plants of the variety "Potentate" were set out in each plot.

In order to assess the effect of treatments, the following plot records were taken:

(a) Percentage of eelworm-infested plants when examined at the termination of the experiment.

(b) Weight of fruit harvested from the first five trusses. This record was completed on the 15th April, 1947.

(c) Weed establishment throughout the period of the experiment, all weeds being counted as they were removed.

RESULTS AND DISCUSSION

Results are summarized in Table I.

TABLE I. EFFECT OF FIVE SOIL FUMIGANTS ON EELWORM INFESTATION, YIELD OF TOMATOES AND WEED GERMINATION

Treatment.	Quantity per sq. ft. (ml.).	Percentage of infested plants.	Weight of fruit per plant (lb.).	Number of weeds per sq. ft.
Check	0.0	91.7	4.8	27.3
Chloropicrin	3.0	2.7	6.8	11.2
D–D	3.0	2.8	5.8	15.2
Carbon disulphide	6.0	83.3	4.8	19.8
Iscobrome I*	3.0	80.5	5.2	18.6
Iscobrome II**	3.0	45.9	6.2	16.5
Difference required for significance at 5 per cent. level		29.9	1.1	6.0
Standard Error		10.0	0.4	2.0

* Iscobrome I—15 per cent. methyl bromide and 85 per cent. xylol.
** Iscobrome II—25 per cent. chloropicrin, 15 per cent. methyl bromide and 60 per cent. xylol.

(a) *Eelworm control.* Results show that chloropicrin and D-D gave almost complete control, while iscobrome II reduced infestation by half. Plots treated with carbon disulphide and iscobrome I showed no significant improvement on check plots. Iscobromes I and II are similar mixtures, except that in the latter 25 per cent. of xylol is replaced by an equal amount of chloropicrin. It appears therefore that the partial control effected by iscobrome II was due to the presence of chloropicrin.

FIG. 1 (*Photo: R. I. Hughes*)

Tomato root from check plots showing effect of heavy eelworm infestation × ⅓.

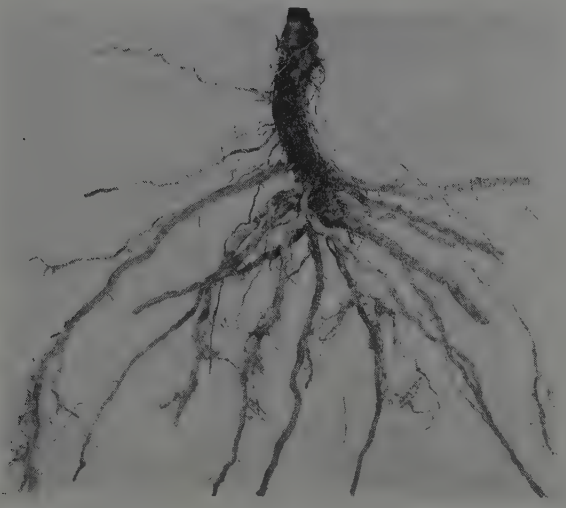

FIG. 2 (*Photo: R. I. Hughes*)

Tomato root from chloropicrin plots showing effect of slight eelworm infestation × ⅓.

Additional to examination of roots for eelworm infestation, observations were made on size and number of galls. In check plots masses of galls up to ½ inch in diameter and 1 inch in length were conspicuous on most plants (Fig. 1). In plots treated with chloropicrin and D-D, galls were few and of small size (Fig. 2). In carbon disulphide and iscobrome I and II treatments, however, galls were numerous and intermediate in size between those in checks and in chloropicrin or D-D.

(b) *Yield of tomatoes.* Compared with checks, chloropicrin and iscobrome II gave significant increase in crop. D-D just failed to give a significant increase while iscobrome I and carbon disulphide were ineffective.

Although chloropicrin and D-D gave equal control of eelworm, the increase in yield was higher in the former treatment. In this connection results secured previously (Jacks, 1945) indicated that chloropicrin applied to clean soil gave a greater increase than D-D in yield of tomatoes. An improvement in the nutrient condition of the soil following use of chloropicrin was also reported by Schchepetelnikova and Cheremisova (1937) and Tam (1945). It is therefore suggested that increased production of fruit in chloropicrin treatments as compared with those of D-D may be due to improved soil fertility.

(c) *Weed control.* All treatments gave significant reduction of weed population as compared with checks, chloropicrin being the most effective. However, as only partial control was obtained it appears that reduction of weeds by soil fumigants cannot be regarded as more than an advantage incidental to their use.

Economic Possibilities

By the present injection method, approximately 1½ man hours would be required to treat 1,000 sq. ft. of area. Although effective control of eelworm under field conditions was obtained by chloropicrin and D-D, at the present time costs of labour and materials for treating other than small areas would be prohibitive. D-D being only ⅙th the price of chloropicrin, shows greater economic possibilities for control of eelworm.

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REVIEW.

BIOLOGICAL STANDARDIZATION OF THE VITAMINS.

K. H. COWARD

2nd Edition, 1947

Since its first appearance in 1937 this book has been the vade-mecum of every worker engaged in biological estimation of the vitamins. That in the second edition (1947) so little alteration to the existing text has been necessary, is in itself a tribute to the soundness and comprehensiveness of the original. Its clear statement of the principles governing biological assay, with emphasis directed to the absolute necessity, in every determination, for simultaneous trial of standard of reference and test material, remains in 1947 as in 1937, the rock on which vitamin determinations must rest.

In this edition a chapter on biological estimation of vitamin E is added to the sections on assay of vitamins A, B_1, C and D. For each of these vitamins, methods of assay are fully described, preparation of animals and plan of experiment are discussed, and careful assessment is made of the merits and demerits of the various methods. For each individual vitamin also, procedure for establishment of curves of response and calculation of results on a statistical basis is explained so clearly as to be understandable even by the non-mathematically minded; while a second section of the book provides a mathematical consideration of factors influencing accuracy, and of limits of error in biological measurement.

Chemical and physical data concerning the international standard preparations are included, and in the case of vitamin A, correlation of biological with physical and chemical methods of assay discussed. Evidence of interdependence of the various vitamins is examined, and attention drawn to the need for careful planning of experiments so that statistical treatment of the results may be employed to yield information on this matter.

The book is not only indispensable to the worker on biological estimation of the vitamins, but provides stimulating reading for all those concerned with the design of animal experiments.

M. M. C.

IMPERIAL AGRICULTURAL BUREAUX

A new journal of the Imperial Forestry Bureau is now being issued entitled "FOREST PRODUCTS AND UTILIZATION." It is a reprint of *Forestry Abstracts*, Section 3.

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